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ACCESSIBLE INFORMATION VISUALIZATION FOR LOW LITERATE USERS: AN ITERATIVE PROCESS OF USER EXPERIENCE DESIGN

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ABSTRACT

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This study focuses on how to build accessible information visualization for low literate (LL) users. It was carried out with technology company, WorkAhead. WorkAhead surveys people through video conversation technology and helps enterprises interact with workers in the supply chain. After the survey, the results are not accessible to LL users. To change this, an effective design that LL users can understand is needed. The primary goal of this study is to visualize the survey results into illustrative graphics that LL users are able to understand. The secondary goal is to focus on the medium of delivery of information.

To meet the goals, three LL users were interviewed in order to find their mental models regarding basic visualization methods. Based on the responses and design guidelines, an initial interactive prototype was built. The initial prototype was further improved and implemented into a final functional one. There were two graph animations embedded in the final prototype: split graph and clock graph. The graph animations were evaluated with the users. Six participants were interviewed and observed while they interact with the final prototype. Most of the participants easily understood split graph animation whereas only one participant understood clock graph.

The results from this study show that an interactive visualization, along with the use of animation, can make data understandable to LL users. This study proves that the responsive behaviour of design and its availability on the web can increase accessibility to LL users. The findings of this study can be utilized as guidelines in research and design for LL users. It also became apparent that further research on accessible visualization methods and techniques needs to be done for LL users in future studies.

Key words and terms: illiteracy, low literate users, user experience, human centred design, data visualization, information visualization.

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1. Introduction

Data is everywhere in today's world. Data visualization has changed people's lives in such a way that it has become an integral way of communication. This information age has greatly transformed people's way of thinking and communicating. As the human brain is attracted to visuals, information visualization is utilized as a tool of visualizing information for amplifying cognition (Kirk Andy, 2016). For this reason, different kinds of visualization methods have been developed over the years. These forms consist of smartly integrated visual patterns that help people to understand and interpret the information.

The human brain processes a vast amount of data every day from different media such as the internet, publishing, advertising, and social media. This huge amount of information needs to be processed and understood for better communication. The world has gradually seen the advanced form of information visualization over the years which has allowed people to understand information quickly and efficiently. This power of processing data is valuable and should be utilized every day in order to navigate the huge amount of data (Lankow, Crooks & Ritchie, 2012).

Information visualization has made people's lives easier by transforming this large amount of data into a visual format. According to Lankow et al. (2012), visualizing of information has been applied as a communication tool mostly by science, academia, and publishing. However, information visualization is not limited to only these fields. Nowadays, every organization and enterprise in the emerging markets utilizes various methods to visualize their data in order to reach their clients and customers.

This study was carried out with a technology company, WorkAhead. WorkAhead surveys people through video conversational technology. This technology helps enterprises to interact with their workers in the supply chain. The educational level of workers that take part in the survey vary from high to low. When the survey is taken, the report of the results is sent to the enterprises. The data visualization of the survey report plays a vital role in WorkAhead's aims of contributing to sustainability and human rights. However, due to illiteracy, the current visualization of the report may not be accessible to the workers who took part in the survey. A common principle of ethical research is

to provide the report of a survey. Therefore, there is a need for visualizing WorkAhead's data targeting low literate users.

International Literacy Association (1996-2019) defines illiteracy as an inability to identify, understand, interpret, create and communicate in any kind of subject that requires reading and writing capabilities. According to a UNESCO report (UIS, 2017), there are still 750 million people who are unable to read and write. Most of them are from developing countries. In this modern world, the inability to read and write definitely has an effect on the progress of the nation. Along with that, low literate (LL) are less familiar with user interfaces. In addition, there are numerous challenges they face in their daily life due to illiteracy. Therefore, there are many elements to consider while designing a system for people who lack literacy skills.

The design guidelines provided from existing research are more for mobile applications, information search, and other similar technologies in general. However, there is little research on information visualization for people who lack literacy skills. Even though information visualization plays an important role in communicating and amplifying cognition, LL population have not been considered as a target group. As a result, LL population are still behind and several organizations such as WorkAhead who work for LL population have difficulties in collaborating and communicating with them. The inability to access written communication make LL users a difficult user group to reach. Thus, there is a clear research gap on how the information visualization is made accessible to LL users.

Therefore, to fill the gap and address the problem of WorkAhead, this study aims to design a complete user experience (UX) design process of information visualization for LL users. The design is implemented to a functional prototype and tested for identifying improvements. The primary goal of this study is to visualize data into illustrative graphics that LL users are able to understand. The secondary goal is to focus on the medium of delivery of the visualization. These goals are reflected as research questions which are listed below:

1. How can WorkAhead's survey results be visualized so that they are understandable to people who lack literacy skills?
2. How can the visualization be defined and delivered to them?

The rest of the thesis is organized as follows. Chapter 2 covers the concept of literacy, illiteracy, and the levels in between. It focuses on the levels based on one's capabilities and skills. Along with that, the chapter concludes with why the neutral term "low literate" is utilized in this study. Chapter 3 discusses the design principles which are applicable when designing for low literate users. It categorizes principles by considering the LL user issues such as their behaviour, capabilities, psychological factors, social and economic factors. Chapter 4 focuses on the definition and importance of information visualization for LL users. Furthermore, it briefly explains the representation techniques suitable for LL users which are commonly in use in today's world.

Chapter 5 explains UX design process along with human centred design approach, which is the complete basis of analysis carried out in this study. It describes the methodology used, which starts from the process of understanding users, creating an initial prototype, and ends with implementation of a design solution. It also introduces WorkAhead and its users, for whom the design is created. Chapter 6 describes the evaluation and testing of the functional prototype along with the identification of improvements. Chapter 7 covers discussion of the findings and challenges faced during this study. Finally, chapter 8 concludes the thesis with a short summary of the work carried out and provides suggestions for further research.

2. Defining illiteracy

The concept of illiteracy is adequately derived from the definition of literacy. The International Literacy Association (1996-2019) defines literacy as *“the ability to identify, understand, interpret, create, compute, and communicate using visual, audible and digital materials across disciplines and in any context.”* This definition clearly is in terms of the adult’s capabilities for performing their daily life activities in today’s society (International Literacy Association, 1996-2019). This means that illiteracy can be defined as an inability to identify, understand, interpret, create, and communicate in any kind of subject that requires reading and writing capabilities.

The concept of literacy has evolved over the years. UNESCO in the 1970s defined illiteracy in simple words, as *“the inability to read and write.”* It designates that an adult can neither identify words nor write single letters (Fuchs-Brüninghoff, Kreft & Kropp, 1986, p.6). Thus, illiteracy in basic form can be defined as the state or condition of people who have little or no educational background. This means that a person is able to speak his/her native language but is unable to read the words and letters of any language.

According to the UNESCO Institute for Statistics (2017), the literacy data over the last 50 years showed 80 percent growth in literacy skills of adults. However, there are still 750 million adults globally who are unable to read and write. Among them, two-thirds are women, and most of the illiterate population are from developing countries. In developed nations, only 1 to 2 percent are illiterate. However, even a small percentage has a moderate effect on the growth of a nation (UIS, 2017). Therefore, illiteracy can be considered as an important topic for any nation.

The process of eradicating illiteracy started since the mid-1960s when several studies showed that literacy is a solution for socio-economic problems (UNESCO, 2004). UNESCO identified several benefits of literacy at the level of individual, political, cultural, social, and economic factors. At an individual level, a person has benefits of self-esteem and empowerment whereas at the political level, a person has the benefit of political participation, democracy, and ethnic equality. At a cultural level, a person can participate in preserving his/her cultural diversity and be constantly active and open for cultural issues. Furthermore, at a social level, a person can get benefits of health, gender equality

and education. Finally, at an economic level, a person has benefits of economic growth individually and an opportunity to invest for economic development in his/her country (UNESCO, 2006).

Due to many benefits of literacy, a common view formed is to eradicate illiteracy. Eradication was possible only when characteristics of literacy are understood from its root level. In the 1960s, a single definition of literacy was seen too narrow to capture the importance of literacy. It was considered as not explanatory enough for understanding its meaning. Hence, a new concept called “functional literacy” was introduced relatively for socio-economic development. Functional literacy familiarized the concept of not only reading and writing abilities, but also arithmetic skills as a necessary factor for development. Since then, the characteristic of literacy has more evolved into different levels (UNESCO, 2004).

While focusing on the concept of functional literacy, at the general conference of UNESCO in 1978, literacy was categorized into four levels and given a proper standard definition. The categorization sorted adults into literates, illiterates, functionally literates, and functionally illiterates (UNESCO, 1978). It helped to understand the differences between literates and illiterates. In addition, it also helped to interpret characteristic and distinguish the various levels in between.

The categorization, which is shown in table 1, introduces the concept and differences between adult literacy and functional literacy. Adult literacy consists of two levels of people, literates and illiterates. Similarly, functional literacy has two levels, people who are functionally literates and functionally illiterates. The term ‘functional’ differentiates the definitions between adult literate and functionally literate. This means that a literate person is not necessarily functionally literate. Vágvölgyi et al. (2016) justified that literates who had attended school and are able to read or write whereas illiterates had never attended the school and are unable to read or write even single words. Furthermore, Boltzmann and Rüsseler (2013) explained functionally illiterates as “people who have attended school for several years, but who failed to acquire functional reading skills.” They have cognitive deficits, or they have problems even reading short simple words (Boltzmann & Rüsseler, 2013).

Table 1. Definitions of illiteracy for statistical purposes (UNESCO, 1978, p.18)

Group	Definition
Literate	A person who can understand both reading and writing a short simple statement in everyday life.
Illiterate	A person who cannot understand both reading and writing a short simple statement in everyday life.
Functionally literate	A person who can engage in all those activities in which literacy is required for effective functioning of group and community and also for enabling to continue to use reading, writing, and calculation for his own and the community's development.
Functionally illiterate	A person who cannot engage in all those activities in which literacy is required for effective functioning of his group and community and also for enabling to continue to use reading, writing, and calculation for his own and the community's development.

Table 1 explains adult literacy and functional literacy in detail. However, the concept and definition of illiteracy vary according to culture, way of living, language and socio-economic conditions (UNESCO, 2004). For instance, in some countries, people who can read the letters are considered as literate whereas, in other countries, people need much more advanced skills in order to be considered as literate. Therefore, it is difficult to measure the levels in these kinds of circumstances. For example, sometimes a person is able to read but not to write (Lestage, 1982). Thus, noticing the gaps and differences between the levels within the literacy led to many kinds of research to understand literacy and its characteristics.

In 1986, UNESCO proposed a new model taking into account of linguistic competence. This proposal reflected the categories of adults who find it hard to read and write in their everyday life. Table 2, in contrast to Table 1, describes and distinguishes the distinct abilities of illiterate adults.

UNESCO's new model included all characteristics of literacy, taking into account the capability of adults who have poor reading and writing skills. This categorization covers adults who are considered as illiterate in some countries and literate in other countries. In addition, this can also represent the differences in linguistic characteristics between children and adults in their reading and writing capabilities. Hence, the levels can be assigned to any kind of individuals

who have poor skills in reading and writing. However, they can be considered useful only to diagnose the linguistic ability of a person and cannot be applied during the learning phase (Fuchs-Brüninghoff, Kreft & Kropp, 1986).

Table 2. Levels of adult illiteracy (Fuchs-Brüninghoff, Kreft & Kropp, 1986, p.7)

Levels	Abilities
First level Adults	People who are capable of writing their name and address, who recognize a certain number of letters of the alphabet and are also able to identify these letters when they occur in a word or a short sentence. Short words and words which are frequently encountered can often be assigned to photographs or drawings.
Second level Adults	People whose ability to read is slightly better than their ability to write. These adults can read words which they come across in their everyday lives and they generally understand short written messages. The construction of their own written words is often a difficult task because letters as well as parts of a word are frequently left out.
Third level Adults	People whose abilities are much more advanced, especially as far as reading is concerned. These adults are often able to read a newspaper slowly, but they feel very inhibited in their writing owing to their perceived shortcomings in this area. These adults do not for the most part use the written word as a medium of communication.

Further studies have continued to develop the concept and levels of literacy. UNESCO used the Literacy Assessment and Monitoring Programme (LAMP) framework tool to collect data about the illiteracy in both developing and developed countries. It facilitates to compare the literacy data of several countries. It was categorized into levels on the scales of proficiency in order to understand the depth of characteristics hidden in literacy. Table 3 lists the five proficiency levels.

Despite the missing gaps and differences in the introduced concepts of literacy, these models are generally used in the fields whose efforts are to eradicate illiteracy. Most importantly, the levels are used to understand the people and their capabilities in terms of their literacy skills.

Table 3. Five Levels of literacy (UIS, 2007, p.3)

Levels	Representation
Level 1	Persons with very poor skills, where the individual may, for example, be unable to determine the correct amount of medicine to give a child from information printed on a package.
Level 2	Respondents can deal only with material that is simple, clearly laid out, and in which the tasks involved are not too complex. It denotes a weak level of skill, but more hidden than Level 1. It identifies people who can read but test poorly. They may have developed coping skills to manage everyday literacy demands, but their low level of proficiency makes it difficult for them to face novel demands, such as learning new job skills.
Level 3	Suitable minimum ability for coping with the demands of everyday life and work in a complex advanced society. It denotes roughly the skill level required for successful secondary school completion and college entry. Like higher levels, it requires the ability to integrate several sources of information and solve more complex problems.
Level 4 and Level 5	Respondents who demonstrate a command of higher-order information processing skills.

As the variations and different level of characteristics in illiteracy are inevitable. The term “illiterate” independently does not cover all groups of individuals falling in between the categories. Along with that, Oxford (2018) specified that the term “illiterate” in some societies mapped the impression of judging one’s capability and was considered to have a negative form of describing a person. Therefore, neutral terms such as “low literate” or “non-literate” are used in today’s world (Oxford, 2018).

Consequently, this study adopts the concept of calling users as “low literate” (LL) and discards the term “illiterate”. As the diverse frameworks demonstrate, there is no single agreed definition of illiteracy. The most established models, Table 2 and Table 3, however, are helpful in finding characteristics difference in literacy levels. These levels can be used by designers and developers in any field where a study of literacy needs to be carried out.

This chapter discussed illiteracy and its various levels. The next chapter explains briefly about design guidelines when the target group is LL users. These guidelines are followed to implement the design of an end product of the work presented in this study.

3. Design guidelines for low-literate users

According to Alfredo et al. (2010), there are two main reasons of illiteracy: Social reasons and Personal reasons. Social reasons may be due to lack of educational facilities, child labour, social beliefs, and poverty. Personal reasons include disabilities and mental issues such as motor and sensory problems. Personal reasons can be controlled to some extent, but it is impossible to eradicate them. However, the social reasons can be controlled and manipulated over the course of time. They are the main reasons that affect people individually as well as socially. All the social reasons are interconnected, with one factor which is not being able to access quality educational facilities. Schooling enhances and improves the cognitive ability of a person. Therefore, illiteracy directly impacts the cognitive abilities of a person. Thus, it is evident that low literate population have lower performance level than literate population, as they are trained and their ability to think is reinforced during their schooling (Ardila et al., 2010). As a result, it would be imprudent to assume LL user's cognitive ability is at the same level of that of the literate population.

There are many differences between low literate and literate population. A deeper understanding of their behaviours, mental models, motivation, and capabilities is required before developing a design or a product for low literate (LL) users. Thus, this chapter explains the list of design guidelines found in previous research that can be applied when designing for LL users. The guidelines are categorized based on user's issues such as their behaviour, capabilities, psychological factors, socio and economic factors.

3.1 Design guidelines for illiteracy and unfamiliarity with technology

The challenges include lack of reading and writing skills and lack of exposure to technology. Lack of reading skills is not the only problem that low literate users deal with when using a technology in general. Only few user interfaces are designed taking LL users into consideration. The user interfaces designed for literate users can be challenging for LL users. As a result, they do not have much choice and are less drawn towards using such technology (Huenerfauth, 2002).

An ethnographic research design process to map application for illiterate users conducted by Medhi, Sagar, and Toyama (2006) in urban slum communities of India showed that their LL participants, who could not read or write, could read

numbers. They recognized numbers easily. Hence, the first design requirement for illiteracy is emphasizing text free user interfaces. This means text should be avoided as much as possible because heavy use of text makes it difficult for LL users to access the functions and services (Medhi et al., 2006).

On the contrary, Medhi et al. (2006) recommended using a little bit of text along with audio to support in the learning process of users. As literacy is dynamic, use of text can help second level adults (see Table 2) enhance their learning. In addition, Medhi et al. (2006) used voice feedback because they realised that their participants were excited and joyful every time audio was played. This means the use of multimodality may help to provide access to LL users. For example, speech interaction in the local language would make LL users comfortable. Not only voice feedback but also providing audio assistance in all possible screens can be the ideal design solution when designing for LL users (Medhi et al., 2006).

Moreover, implementing visuals and graphics promotes the understandability of various functions, elements, and actions in the system. Interactive icons make sense when there is very little use of text. In addition, the icons should be very representative so that they would represent the meaning (Chang, 2008). Avoiding abstract graphics is most important since LL users have very little experience with technology and its trends. The meaning of radio buttons and other UI elements might not make sense to them. For example, when testing a map application, Medhi et al. (2006) found out that animated arrows in the map were not recognized by the participants. However, using small icons of cars instead of arrows immediately made sense to them. Likewise, when hovering over roads in the same map application, it turned yellow. This was not understood by all of the participants. They gave feedback saying roads are never yellow. Therefore, the elements that have an actual meaning in real life should be integrated in the design so that they make sense to LL users and they are able to use the system without an assistance (Medhi et al., 2006).

On the other hand, Huenerfauth (2002) argued that icons should not be used as an all-time solution for problems related to illiteracy. They should not be used to express information which would confuse the users. He also recommended that several appropriate animations could help LL users to understand the meaning behind the usage of interface. Animation adds life to images and graphics and is an effective way of communicating with LL users (Huenerfauth, 2002). Lalji and Good (2008) suggested that when replacing text by icons and symbols, making

assumptions and implementing abstract cues should be avoided. The inability to read and write as well as being a novice with the technology means less ability to understand the hidden actions implemented in the design (Lalji & Good, 2008).

3.2 Design guidelines for cognitive issues

The challenges include less cognitive capabilities and low performance level of LL users. Research done by Kodagoda and Wong (2008) involves a study between LL and literate participants. The study was done to map out how low or high literacy has an effect on the performance level. The participants were assigned tasks of seeking information online. The results showed that LL participants took 8 times longer than literate participants to complete the task. Besides that, completed tasks were noticeably less accurate (Kodagoda & Wong, 2008). This shows that the low performance level of LL users when using a technology is a challenge for designers.

Modesto, Ferriera, and Alves (2013) claimed that LL users have less tendency to recover from errors. Their research involved observations of low literate participants to test interaction with search engines. On the basis of their observations, they found out that LL users could not handle too much information at a time. Therefore, they recommended that only 7 main actions (or 9 at highest) should be displayed at a time. In addition, Modesto et al. (2013) stated that LL users, because of having little or no reading skills, tend to get confused with lot of text. If there is a necessity of implementing text, only limited amount of text should be used. Along with that, text should be clearly visible with the use of proper size. Thus, there should be limited number of actions implemented when designing for LL users (Modesto, Ferreira & Alves, 2013). Overall, the idea is to design an interface with minimal elements that decrease memory load and reduce confusion.

The complexity of learning the meaning of a picture is similar to that of reading a text. While choosing icons and graphics, noticeable ones should be chosen. Thus, icons or images with proper size that clearly explain the meaning are more effective. Similarly, icons should be easier to name, remember, and understand so that users can relate them to their daily life activities and discuss with each other (Huenerfauth, 2002). For example, Figure 1 was used as a way to describe activities in a research of Indian slums by Medhi et al. (2006). Running tap water, a burning stove and sliced vegetables were understood as actions of cooking.

Without these elements, participants understood the drawings as a location i.e. a kitchen (Medhi et al. 2006).

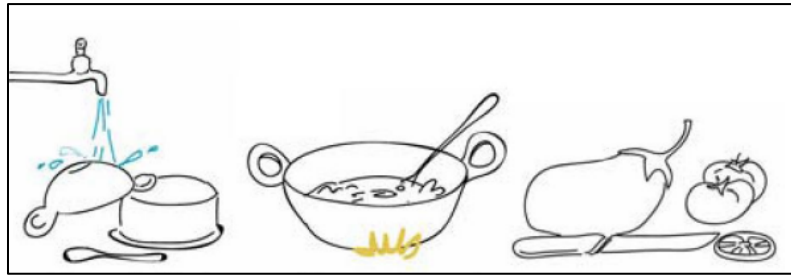


Figure 1. Icons with action cues. Reprinted From “Text-Free User Interfaces for Illiterate and Semi-Literate Users”. By I. Medhi, A. Sagar, and K. Toyoma, 2006, 2006 International Conference on Information and Communication Technologies and Development, p.74. Copyright 2006 by IEEE.

Medhi et al. (2006) also suggested that audio help could be a solution for LL users. Audio help will enhance their cognitive capabilities since the users do not need to memorize all the actions. Speech interaction with the approach of providing feedback in an informative way may enhance usability as well as give encouragement to use the design interface (Medhi et al., 2006).

3.3 Design Guidelines for psychological factors

The psychological challenges include low confidence and intimidation when using technology. Brosnan (2002) claimed that the issues of LL users are mainly related to confidence rather than their cognitive abilities. These users avoid technology because they are intimidated by it. They have a fear of damaging the equipment because they feel they are not intelligent enough to use it. Consequently, they tend to avoid technology (Lalji & Good, 2008).

The most important requirement is to enhance their confidence level and encourage them to manipulate the interface. Not only LL users but also literate users, are likely to get intimidated by a complex design. However, in case of LL users, the issue is more sensitive. For example, long lists of text can be very intimidating. To address these problems, use of white space can be a very effective method. It can reduce their anxiousness. Likewise, less clutter and more organized elements can be an adequate way to boost their confidence. In addition, use of several colours like red and yellow could attract attention and increase a sense of likeability. Overall, simple design gives sense of learning and ease of remembrance which makes LL users less afraid and get more interested

in using technologies. Further, the complexity of the system should increase little by little to promote their learning and increase their confidence (Kodagoda, Wong, Rooney & Khan, 2012).

Sense of familiarity attracts user's mind and increase their curiosity level. For LL users, familiar graphics can be a very useful factor to draw their attention. Also, they can relate to terms of their everyday life. This results in an increase in their confidence level. Figure 2 shows an example of research of Indian slums done by Medhi et al. (2006) for a map application in the city. When the design of a house icon for a residential area was used (as shown in Figure 2a), LL participants perceived the house icon as a village hut. When being asked about it, they responded that the shape of house icon is similar to a village hut. Similarly, their understanding of higher income people is living in tall buildings. Therefore, Figure 2a was changed to a building icon as shown in Figure 2b (Medhi et al., 2006).

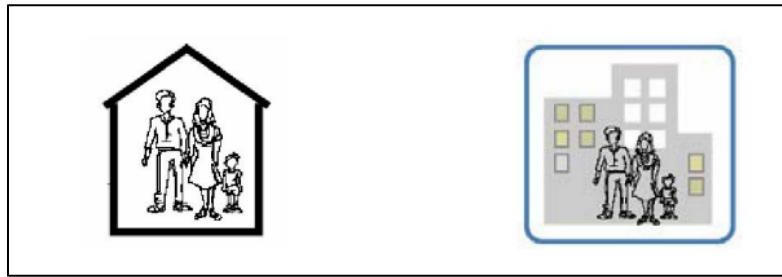


Figure 2a (left) and 2b (right). Two designs for residence icon. Reprinted From "Text-Free User Interfaces for Illiterate and Semi-Literate Users". By I. Medhi, A. Sagar, and K. Toyoma, 2006, 2006 International Conference on Information and Communication Technologies and Development, p.74.

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3.4 Design guidelines for social reasons

The challenges include variation in culture and life expectations and poverty. Most of 750 million illiterate population belong to developing countries (UIS, 2017). The most common reason of illiteracy in developing countries is a lack of education. And lack of education is mainly due to poverty. Poverty brings several kinds of difficulties. LL population with poverty issues have different kind of life experiences, needs, and expectations. They have other issues in life to address rather than focusing on technology. So, a common design of symbols and elements would not make sense to them. A careful analysis of their opinions, requirements in their daily life should be carried out (Lalji & Good, 2008).

Furthermore, when designing for the LL population from developing countries, a complete analysis of their culture and religious values is needed. Their way of thinking, cultural taboos, norms and values should be well researched. The purpose is to prevent them from completely avoiding the design. For this, the idea of localisation is very important when designing for specific target users (Huenerfauth, 2002). The symbols, metaphors and even colours should be carefully used. For example, red in western culture is a sign of power, passion or danger whereas in Asian cultures, red is a sign of joy, celebration, and happy life. Thus, this kind of considerations should be taken into account when designing for LL users with different cultural background (Shutterstock, 2015).

Poverty is one of the reasons of illiteracy, it is quite possible that LL users might not be able to afford expensive devices. So, a design should be accessible through an inexpensive device that LL users with the lower economic background are able to use without hesitation. Typically, people from the lower economic background can only have access to affordable hand-held devices rather than laptops or desktops. In addition, Chang (2008) explains that LL users from developing countries are mostly from rural areas. Particularly in rural areas, there are fewer infrastructures and poor quality of roads. Due to this reason, reach of technology is very limited. Hence, delivering design in hand-held devices solves the problem of mobility and portability (Chang, 2008).

Rural LL users may not be able to afford personal devices. Often, they share personal devices within their families and communities. Also, in the culture of most of the developing countries, there is lack of understanding of privacy. Personal property is shared by family members. These kinds of limitations and way of using technology should also be considered as an important guideline, focusing on making accessible design when targeting LL users from developing countries (Chang, 2008).

4. Information Visualization

This chapter describes the definition and importance of information visualization for LL users. In addition, it briefly explains the representation techniques suitable for LL users which are commonly in use in today's world.

4.1 Definition and its importance for low literate users

Information visualization has been used as a communication medium for hundreds of years. The first forms of information visualization were cave paintings. Early cave paintings evolved to medieval period visuals and finally to modern data visualization methods. Some of the methods are still utilized in today's world of visualization. Kirk Andy (2016, p.4) pointed out that the pie, line, and bar charts, which originated in the 18th century, are still dominant methods of visualization.

Kirk Andy (2016, p.13) defined information visualization as a process of representing and presenting data that exploits human visual perception abilities in order to amplify cognition. The human brain can consume a huge amount of data, around 100,000 words in a day. If the numbers exceed more than 100,000, the human brain perceives the information as noise and gets it permanently removed due to the load. People come across an extreme amount of information in their daily life. For instance, from published newspapers or magazines, the World wide web, email, social media, and so on. The scattered information does not provide comforting experience to the eyes and brain. This proves the necessity of visualizing information into both an engaging and informative way. Visualizing information in an interesting and captivating way, can be followed in order to prevent load for the brain (Kirk, 2016, p.6).

Moreover, Kirk Andy (2016, p.11) stated that visualization allows LL users to take advantage of one of their strengths of human visual capabilities. He also stated that information can be interpreted just by eyes; a brain simply does not need to function in order to understand the data. In other words, brain does not require huge amount of thinking because eyes can simplify the job of interpretation. Not only that, but visualization also provides entertainment with captivating visuals which can also act as a motivation for LL people (Kirk, 2016, p.11).

Ware (2012) claimed that visualization can result in the formation of hypotheses. After a clear understanding of data, it can lead to some questions that have never been realised before. This can lead to many discoveries which usually do not occur easily in the thought process of human. Visualization makes the possibility of organising a large volume of data in a very short amount of time. Huge amounts of data can be measured and interpreted easily. Within data, there can be several categories, their differences and relationships. Use of visualization helps to interpret all sorts of complex data and understand the correlation between them (Ware, 2012).

Shneiderman and Plaisant (2005, p.581) explained that information visualization helps to answer the questions that people did not know they had in mind. With an appropriate way of visualization, several hidden errors and artefacts can be figured out. This indicates that data visualization also plays a vital role in quality development. Humans have an extraordinary way of perceiving visuals. They have an ability to achieve more information through vision than any other senses combined. They can detect, scan, memorize visuals promptly. They can notice even small changes in the form of shape, size, colour, motion, quality, composition and so on. Thus, visualization is one of the capabilities of the human cognitive system. Shneiderman and Plaisant (2005, p.580) described the importance of visual representation for a human brain as:

“A picture is often said to be worth a thousand words, and for some tasks, a visual presentation such as a map or photograph is dramatically easier to use or comprehend than is textual description or a spoken report.”

Visualizing of information has been applied as a communication tool mostly by science, academia and publishing for centuries (Lankow et al., 2012). This shows that information visualization is dominant only among literate population. Looking at the advantages of information visualization, the most suitable user group are LL people. The benefits have not been fully utilized by the most vulnerable population who face numerous challenges daily due to lack of literacy skills.

Minard map in Figure 3 and Google map in Figure 4 are two different examples of visualization. The Minard map was made in 1812. It represents the marching of Napoleon’s army towards Russia. The direction of army is illustrated by the colour of the paths. Gold path is leading army into Russia whereas black path is

leading out of Russia. The narrow path represents the number of armies remaining. As the army marches, the path narrows down slowly. Additionally, at the bottom of the map, it illustrates the temperature of Russian winter in degrees (Jacobs, 2010).

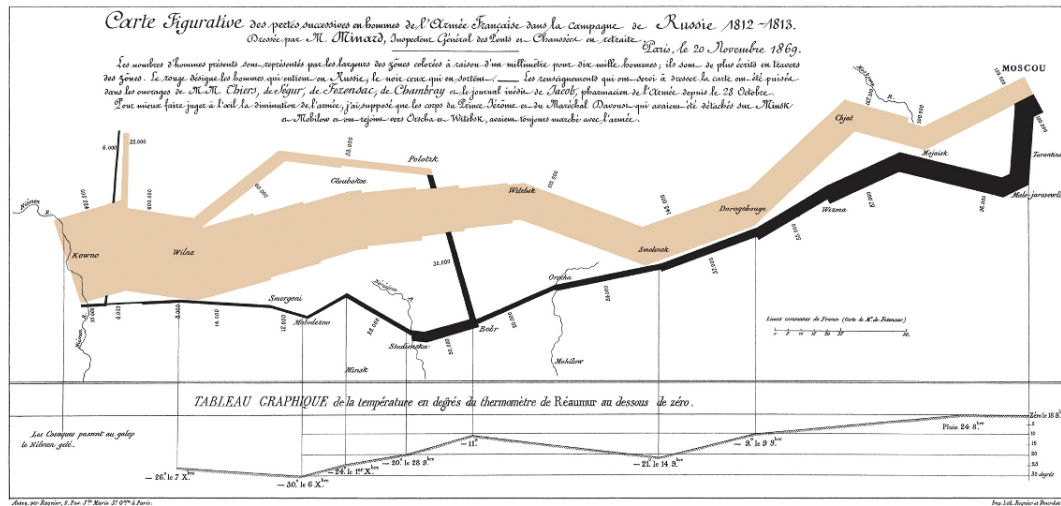


Figure 3. The Minard map: Flow map of Napoleon's army marching into Russia in 1812.

Reprinted from *Infographics: The power of visual storytelling* (p.32), by J. Lankow, R. Crooks and J. Ritchie, 2012, Hoboken, New Jersey: John Wiley & Sons. Copyright 2012 by Column Five Media.

Tufte (2002) stated that Minard map is one of the best graphics shown statistically in the history of mankind. The use of colour coded army paths and geography such as rivers, cities and battles are remarkable. The map visualizes six different sets of data and yet it is simple and easy to follow (Tufte, 2002). Thus, the Minard map can be considered as the best example of how information can be visualized for amplifying cognition of human brain.

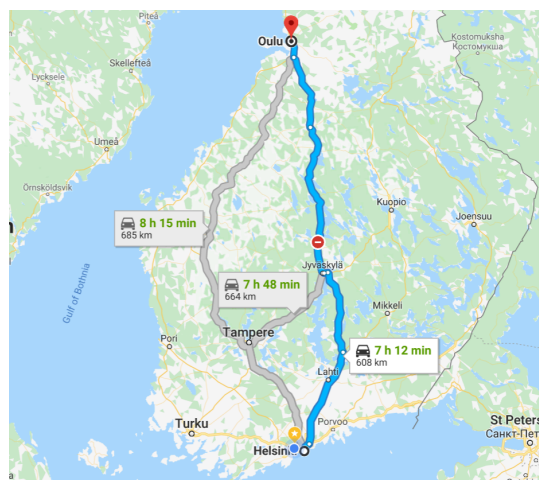


Figure 4. Google Map showing routes from Helsinki to Oulu. Adapted from *Information Visualization: A Brief Introduction*. Retrieved from <https://www.google.com/maps>. Copyright 2019 by Google Inc.

According to the Interaction Design Foundation (2019), Google map is a very simple and relevant way of showing routes. Figure 4 communicates only the required information to users about the start to end points of their journey. It also represents information about other possible routes. Additionally, it highlights the shortest travel route in blue colour whereas other routes are in grey. Figure 4 is a map retrieved from Google and is an excellent way of visualising routes and times along with the location and distance (Interaction, 2019).

Google map shown in Figure 4 does not require reading and writing skills to understand the visualization. However, the Minard map shown in Figure 3 can be quite challenging to understand for LL users. When information visualization is done carefully along with taking needs of LL users into account, it can solve several problems and challenges caused due to illiteracy.

4.2 Representation techniques suitable for LL users

Like pointed in Section 4.1, LL users have not been targeted for information visualization. There are many representation techniques that are in use in today's world, yet not all are accessible to LL users. All techniques are used in a simple or advanced form. They are utilized according to the dimensions of data. Most techniques require basic arithmetic skills, which LL users do not acquire. Spencer (2014) introduced different representation techniques that vary from very simple to complex level. Some of the main techniques which are suitable for LL users are presented below (Spencer, 2014, pp.43-62). These techniques do not require a high level of literacy, arithmetic skills or cognitive capabilities.

1. Dials

Dials are the surface which shows direction or measurement with a movement of a needle or pointer. Compasses and clocks are the most common examples of dials which show directions and time respectively. These are common devices that are used by LL users in their daily life. So, any visualization related to these devices can make sense to LL users.

Another example of dials is an altimeter. In Figure 5, the altimeter has 3 hands: small, middle and large sized, which indicate the height of aviation in tens of thousands, thousands and hundreds in feet, respectively. The distribution of values is very complex for LL users. In fact, this can be complex for even literate

users. Spencer (2014, p.43) stated that this complexity was a cause of accidents in the past and is no more used in aircrafts.



Figure 5. Altimeter of original aircraft. Reprinted from *Information Visualization: An Introduction* (3rd ed., p.43). by R. Spencer, 2014, London, UK: Imperial College. Copyright 2014 by Springer International Publishing. (Spencer, 2014, p. 43)

Despite the altimeter not being targeted to LL users, this is one example of visualization which has proved that the simplest representation can create confusion to even literate people who are trained to perform a task using the information. In the case of LL users, a further study needs to be conducted when using dials as a representational technique.

2. Mosaic Plots

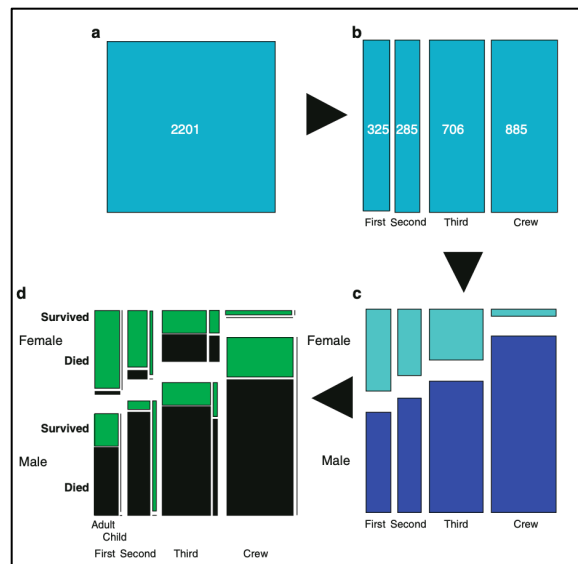


Figure 6. Mosaic Plots (right). Reprinted from *Information Visualization: An Introduction* (3rd ed., pp.50-52). by R. Spencer, 2014, London, UK: Imperial College. Copyright 2014 by Springer International Publishing. (Spencer, 2014, p. 62)

Mosaic plots is a technique that shows values of a group, sub-groups, and so on. Figure 6 illustrates the total number of people who faced the Titanic incident. 6.a indicates the total number of people on the Titanic and 6.b shows them according to the class (first, second & third) and crew. Next, in 6.c the classes are divided into gender. Finally, 6.d shows the number of male and female who died and survived. This technique visualizes the possible breakdowns in a simple manner and represents data step by step.

3. Iconic Representation and Chernoff Faces

Icons do not need textual description because they are an alternative way of visualizing texts. They can make more sense to LL users. For example, a house icon as shown in Figure 7. The iconic representation is the most common way of visualizing data in the modern age.

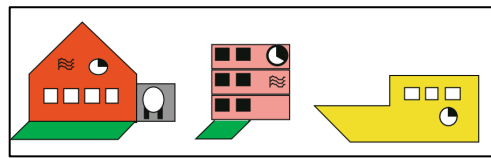


Figure 7. Iconic representation of house, flat and house boat with different attributes of a face.

Reprinted from *Information Visualization: An Introduction* (3rd ed., p.51). by R. Spencer, 2014, London, UK:

Imperial College. Copyright 2014 by Springer International Publishing.

Chernoff faces are an iconic representation of the emotions of a human. In 1973, Chernoff introduced that the facial features have some values to represent facial expression. For example, a millimetre raise in an eyebrow means that there is some reaction hidden in the expression. Facial features like eyes, eyebrows, mouth, nose, and so on can have values and define some characteristics. In Figure 8, the different values of encoded facial features (from left to right) indicate interesting facial expressions such as amazed, worried and angry, respectively. This concept is now widely used as emoticons to show emotions (Spencer, 2014, p. 53).

As mentioned in Section 3.1, icons cannot be used as an all-time solution of representation for LL users. Nevertheless, icons when combined with other techniques such as mosaic plots, dials, and Chernoff faces, can create a design solution that can be understandable for LL users.

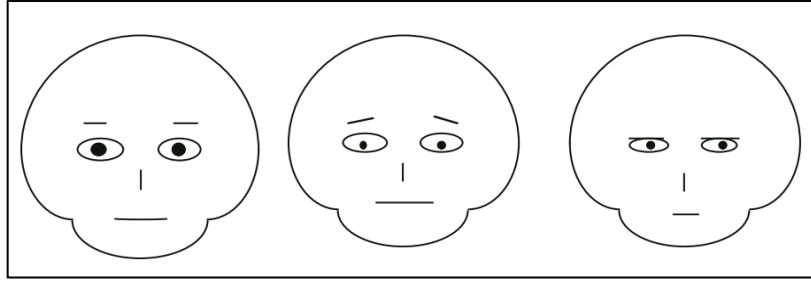


Figure 8. Chernoff Faces with different attributes of a face. Reprinted from *Information Visualization: An Introduction* (3rd ed., p.53). by R. Spencer, 2014, London, UK: Imperial College. Copyright 2014 by Springer International Publishing.

4.3 Challenges for visualization and their possible solutions

According to Shneiderman and Plaisant (2005), it is important to understand the dimension of problems in order to benchmark errorless visualization. Therefore, the upcoming challenges during information visualization should be well known beforehand, particularly when targeting LL users. This helps designers to create a successful design. The following are some challenges during the process of information visualization introduced by Shneiderman and Plaisant (2005, pp.598-600).

a. Data formulation and identifying the correct visualization technique

Importing data into the correct format is the most challenging task for designers during the process of visualization, particularly for LL users. It would be burdensome and tough to decide on how to organise data at first. Next, to find the correct technique of visualization and filtering the correct data is a time-consuming process.

b. Combining visual representation with text

Textual labels play a vital role in visualization. However, the text should be use carefully in case of LL users. The levels of literacy explained in Section 2 prove that some LL users can read but not write and vice versa. This variation in user groups makes it difficult for designers to adopt the right amount of text in visualization. Therefore, finding a proper balance between text and visuals is challenging for designers.

c. Implementation of additional related information

A single visual representation is never enough for LL users to understand the full elements in the visualization. Additional information is needed in order to

understand presented information in depth, especially in case of a large group of data and its hierarchy. Thus, implementing additional information is always challenging.

d. Access to a large volume of data

In the case of a large volume of data, it is problematic to handle. Additionally, it is even more problematic to view large and complex visualization in a single screen. Only larger displays are big enough to show that kind of data, and not everyone owns a large display. This indicates that large volume of data is more likely to be inaccessible to all kinds of users.

e. Achieve universal usability

Users represent people with various background, culture, and most importantly impairments. Information visualization should be indifferent to all kind of diversity. Moreover, delivery of design should also be indifferent to limitations such as a slower internet connection. Along with that, huge data can result in a complex visualization, which can easily intimidate LL users.

Possible solutions of challenges of visualization for LL users

According to Lankrow et al. (2012), drawing simply by using pen and paper for planning can be one adequate way to get started for data formulation. To aim for the right technique, a minimal but illustrative design needs to be targeted for LL users. Moreover, unnecessary sets of data should be discarded to make the data as simple as possible. This means only the necessary elements that represent data should be included. This ensures avoidance of overload and helps in formulating data which is a benefit for LL users (Lankrow et al., 2012).

Without textual labels, 80% percent of data visualization is hard to understand. While designing for LL users, it is recommended to avoid text as much as possible. Nevertheless, text cannot be completely avoided. Thus, textual representation should be done subtly and carefully keeping LL users of the second level in mind (see Table 2 & 3). However, too many texts can intimidate LL users. So, it should be done by finding the right balance in the amount of text. Lankrow et. al (2012) suggested that text size should be consistent and contain no more than two different colours when using text with visuals to avoid clutter.

Animation brings the visualization to life with motion. It engages all kinds of user with attractive features. It provides information and entertains at the same time. Additional information on related data can be shown in the form of animation in order to make LL users understand every hidden detail. Similarly, as a solution to view large sums of data, visualization can be done with the help of animation by breaking the information into different parts and showing the flow of the data from beginning to end. This can be delivered in smaller screens making it accessible to every kind of user (Lankrow et al., 2012).

For achieving universal usability, the use of animation with localised speech interaction can be desirable for users of different cultural and as well as technological background. For visually impaired users, audio description will work easily and for users with colour deficiency, different palettes of colour should be implemented in the design (Shneiderman & Plaisant, 2005).

5. Methodology

This chapter explains the methodology used in this study to create the design solution of information visualization for WorkAhead's LL users. Firstly, it explains briefly about WorkAhead and its goals. Secondly, it introduces a UX design process based on a human centred approach. Finally, it deals with process of creating a design solution from phases 1 to 3. The first phase deals with the process of understanding the WorkAhead's users and the context of use. The second phase deals with identifying user requirements by conducting semi-structured initial interviews and observation of three participants. Apart from that, it also demonstrates a storyboard in order to identify user's needs. Finally, the third phase covers the prototyping and finalising of a design solution based on the user research and requirements from previous phases.

5.1 WorkAhead

WorkAhead is a Helsinki-based technology start-up that helps enterprises speak with their workers focusing on sustainability and human rights. It was founded in 2016. In particular, it works with international companies with supply chains across the world, helping the companies talk directly with their workers. A supply chain is a network of companies, people, activities, and information along with resources involved in the journey of a product from supplier to its customer (Investopedia, 2019).

WorkAhead designs and develops a video survey application. It uses video conversational technology to communicate with workers in emerging markets. The survey application consists of questions which are answered by the workers. The questions are related to the worker's situation and life in general. All the responses are anonymous and confidential. Before conducting a survey, the questions and icons in the application are localized according to the culture, language, workplace, and living conditions of the user group. Thus, the video survey application aims to let workers express their situation, regardless of being unfamiliar with technology, educated or uneducated, rich or poor, and in a junior or senior position. After the survey, the report of the responses is visualized and is forwarded to the concerned organization.

The data received from the workers about their life and work helps the companies improve living and working conditions with their suppliers. The main aim of WorkAhead is to advance human rights, living and working conditions of workers as well as progress towards sustainable development. It focuses on aligning enterprises with their suppliers, creating transparency, and collaborating for improvement. Thus, WorkAhead believes that hearing honest opinions directly from the workers can advance the world where all people work in freedom, peace, equality, and human dignity (WorkAhead, 2019).

5.2 UX design based on Human-Centred design approach

Interaction Design Foundation (2019) defines User Experience Design as,

“the process the creating products that provide meaningful and relevant experience to users which involves the design of the entire process of acquiring and integrating the product, including aspects of branding, design, usability and function.”

UX means the experience of a user when he/she interacts with a certain kind of a product or design. Particularly, UX in simple words can be defined as a good experience when a user meets his/her needs in the context when using a product.

The UX design process is an iterative process. It follows the principle of Human Centred design approach (HCD). ISO 9241-210 (2010) explains HCD approach in four main process. The process involves the description of an entire journey of building a product or design system focusing on users, which this study is based on. The four main phases are described as follows (ISO 9241-210 Switzerland, 2010, pp.10-18):

1. Understand and specify the context of use (Understand)

This phase of the design process involves of understanding the users, their characteristics, goals, and the context of use. The first requirement is to understand the relevant user group of the product. When the user group is understood, their characteristics need to be understood. For example, their skills, experience, education, habits, and way of living should be studied in order to make the product accessible to the targeted user group. Next, the goals and the tasks of user should be recognized. This will help in figuring out the way user perform their tasks. Finally, the context of use of the product needs to be studied. The context of use refers to the environment where the system or product is used.

This covers all the necessary details and assists in boosting the quality of the design to be created. Tools such as personas, scenarios, user story, and use cases can be used in this phase.

In this study, personas are used to understand LL users whereas use case is used to understand context of use of the survey report. Personas is used to know the real users. It includes a person's name, age, profession, experience, attitudes, goals and functionalities. They are based on the research of real people. Similarly, use case included user's actions arranged step by step.

2. Specify user's requirements (Specify)

This phase involves specifying all the functional requirements of the product derived from the user's needs. Particularly, this phase is mainly based on the research that helps in finding a certain set of guidelines of designing the product.

In this study, phase 2 contained three semi-structured interviews to find out user's mental models regarding graphs in general. Brainstorming and ideation were practiced. The literature review of design guidelines and information visualization challenges for LL users was also studied. Storyboard with illustrations is visualized together to show the story between users and their UX with the design.

3. Produce design solutions to meet user requirements (Produce)

This phase adapts the procedure of producing design solutions based on the findings from previous phases. The process includes planning the interaction and designing the user interface according to the design requirements and guidelines found in phase 2. Tools from simple sketching with pen and paper to advanced design tools for creating wireframes can be used in this process to see the prototype version. This process can be iterative until the final design solution meets user requirements.

In this study, Figma, a design software was used to create an initial prototype of design. The prototype is iterated to the final one. The final design is implemented as a web application using React library.

4. Evaluate designs against requirements (Evaluate)

The design solution produced in phase 3 needs to be evaluated. Firstly, the concept of the design can be evaluated by some low fidelity prototype. However, this can also be done in the early stage of designing a product. This can also refer to an early version of a prototype. Secondly, the functionality and usability of the product also needs to be evaluated and this is related to the later stage in the design process. All in all, this phase refers to evaluating of low fidelity prototype to high functional prototype. The evaluation is done by applying various methods of analysing the data.

In this study, the created design solution was evaluated by allowing the LL participants to use the interface and performing the task step by step.

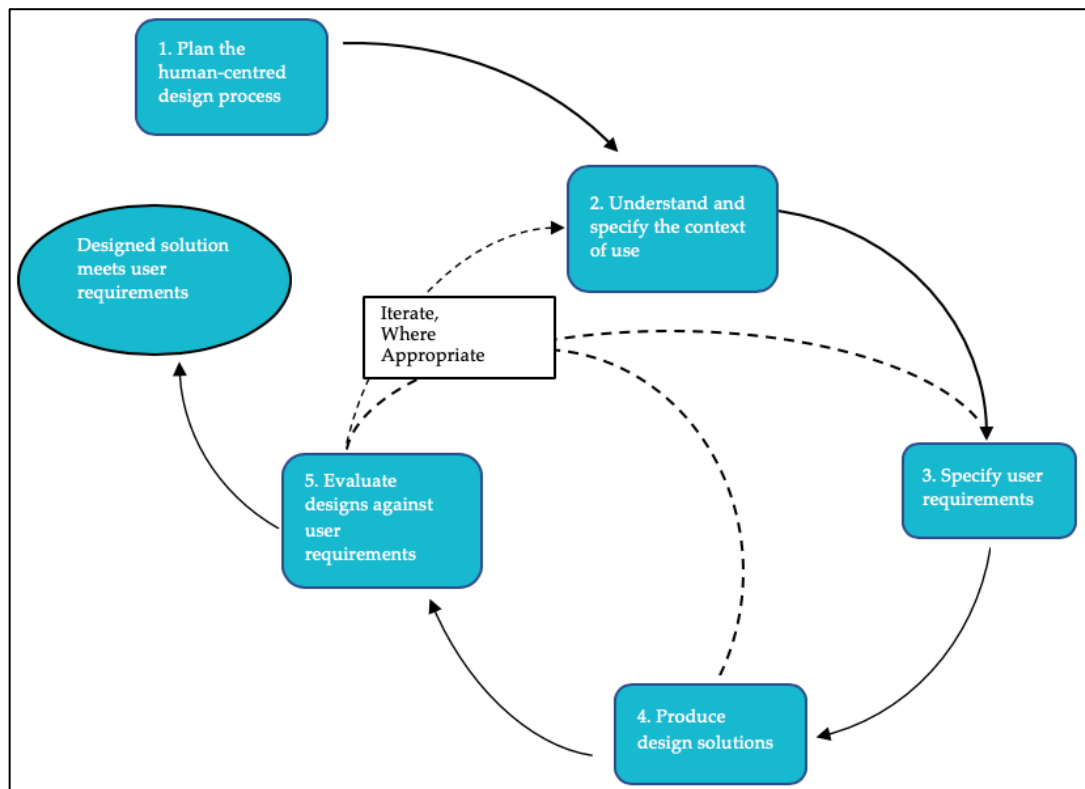


Figure 9. Human Centred Design Process. Reprinted from “Ergonomics of human-system interaction - part 210: Human centred design for interactive systems (ISO/SFS Standard No. 9241-210).” by ISO Switzerland, 2010. Copyright 2010 by ISO 2010.

Phases from 1 to 4 are iterated when appropriate until the design solution meets all the user requirements. Figure 9 illustrates the HCD process in detail (ISO 9241-210 Switzerland, 2010, p.11). The entire design development process in this study is based on these phases of HCD approach. These phases of HCD process are

followed thoroughly throughout the process of designing information visualization for LL users of WorkAhead.

5.3 Research methods

5.3.1 Phase 1: Understanding users and context of use

This section deals with understanding the users of WorkAhead and context of use of the design to be created. Two personas of two different LL users are made to understand their characteristics, behaviour, and motivation in general. To understand the context of use of a survey report, one use case is created and explored.

5.3.1.1 Targeted users

The variation in users of WorkAhead is inevitable. The workers in the supply chain can vary on the basis of their educational level, experience with technology, cultural background, and language in particular. The variations are more less covered by localizing the application. However, due to illiteracy, the report of the survey is not accessible to all of the workers. Some of the workers have never attended school, some have a little educational background, and some can recognize a few letters but cannot read words.

To solve the issue of variations in users, I utilized Table 1, 2 and 3 demonstrated in Section 2 to categorize and recognize the target user group for the design solution of this study. With reference to Table 1, the user group targeted for this thesis is an illiterate group who do not have an understanding of both reading and writing a simple short statement in everyday life. To elaborate the user group, I considered three adult literacy levels from Table 2: first, second and third. All three levels of adults fall under the illiterate user group of WorkAhead. Among them, I focused on the most basic level of ability to read and write i.e. the first level. While doing so, accessible design to be created for first level adults fundamentally covers the abilities of a second and third level of adults. Likewise, in five levels of literacy from Table 3, I focused on understanding Level 1 and 2 low literate adults which automatically covers other higher levels.

5.3.1.2 Personas

In the process of understanding the users, I utilized a tool called personas. To understand the user's motivation, needs, personality traits, behaviours and so on, two personas are created. Persona 1 explains the user with a low educational background whereas Persona 2 explains a user with no educational background, which are shown in Figure 10 and Figure 11 respectively.

Persona 1

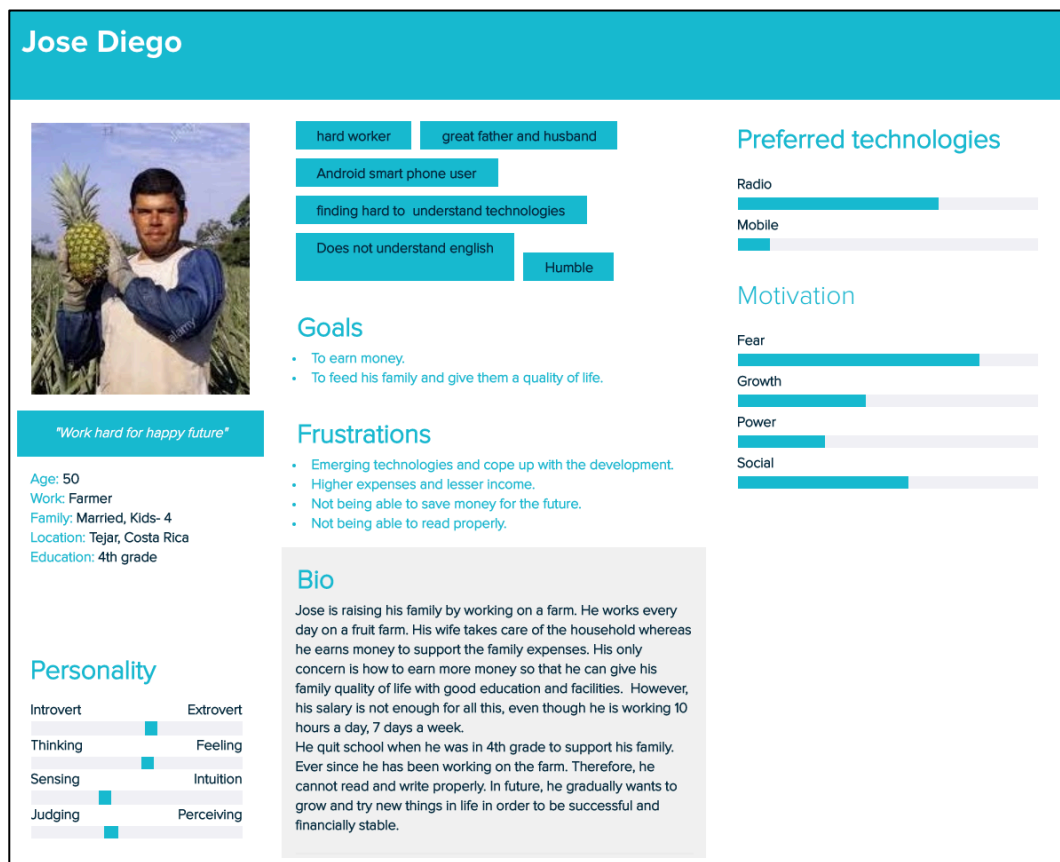


Figure 10. Persona with low education background

The persona of Jose Diego, shown in Figure 10, has a fourth-grade level of education. He has a weak level of reading and writing skills. He can read and write words very slowly which he comes across in his daily activities. According to Table 1, Jose can be considered as "literate" in his country. However, he cannot perform his skills in too complex situations. In this case, he falls under "second level adults" from Table 2 and "Level 2" from Table 3 (Section 2).

Jose is frustrated with his low education background. He fears that he will be left out from the world. So, he wants to learn how to cope with the new development. This means that Jose wants to learn new emerging technologies. For a user like Jose, information visualization can be very new, yet interesting. He wants to learn new things whatever comes under his way. So, a report of WorkAhead can be useful for Jose because he wants to know the situation of his colleagues who work in the same farm.

Additionally, for users who can read slowly word by word, text can be implemented in the report so that the visualized information is clearer and more understandable. Jose is somewhat exposed to a glimpse of technology and can possibly learn when given an opportunity. For example, interactive visualization to play around can be a possible design for users like Jose.

Persona 2

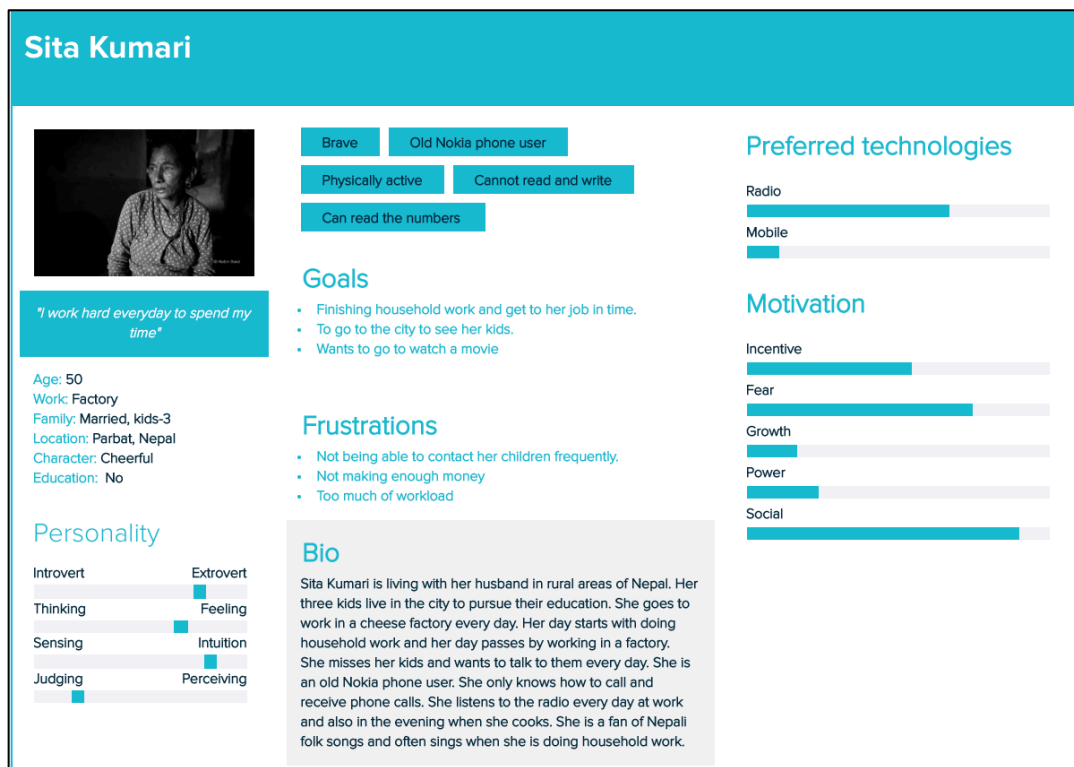


Figure 11. Persona with no educational background

Figure 11 shows that Sita Kumari lives in rural villages of Nepal and has no educational background at all. Her village had a school up to fifth grade, but her parents could not afford to send her to school. She recognizes numbers and can write her own name slowly. She can write her name and address but cannot read

or write even a simple sentence. She falls under “illiterate” group from Table 1, “First level adults” from Table 2 and “Level 1” from Table 3 (Section 2).

For a user like Sita, information visualization is completely new. She is not exposed to advanced technology. In this case, she cannot find sense in the survey report of WorkAhead. However, if carefully done, animation can be a possible way of making elements understandable for her. Instead of using text in the report, attractive ways of animation along with localised audio in Sita’s language can be a possible design solution. Sita is shy in nature and avoids technology whenever she encounters one. Therefore, the design and the animation should not be intimidating. It should be attractive and simple to draw attention of users like Sita. Moreover, Sita needs someone to show the design because she owns a simple Nokia phone. In the case of WorkAhead survey report, a facilitator can be the one who visits Sita’s village and shows her the new design of a survey report.

5.3.1.3 Use Case

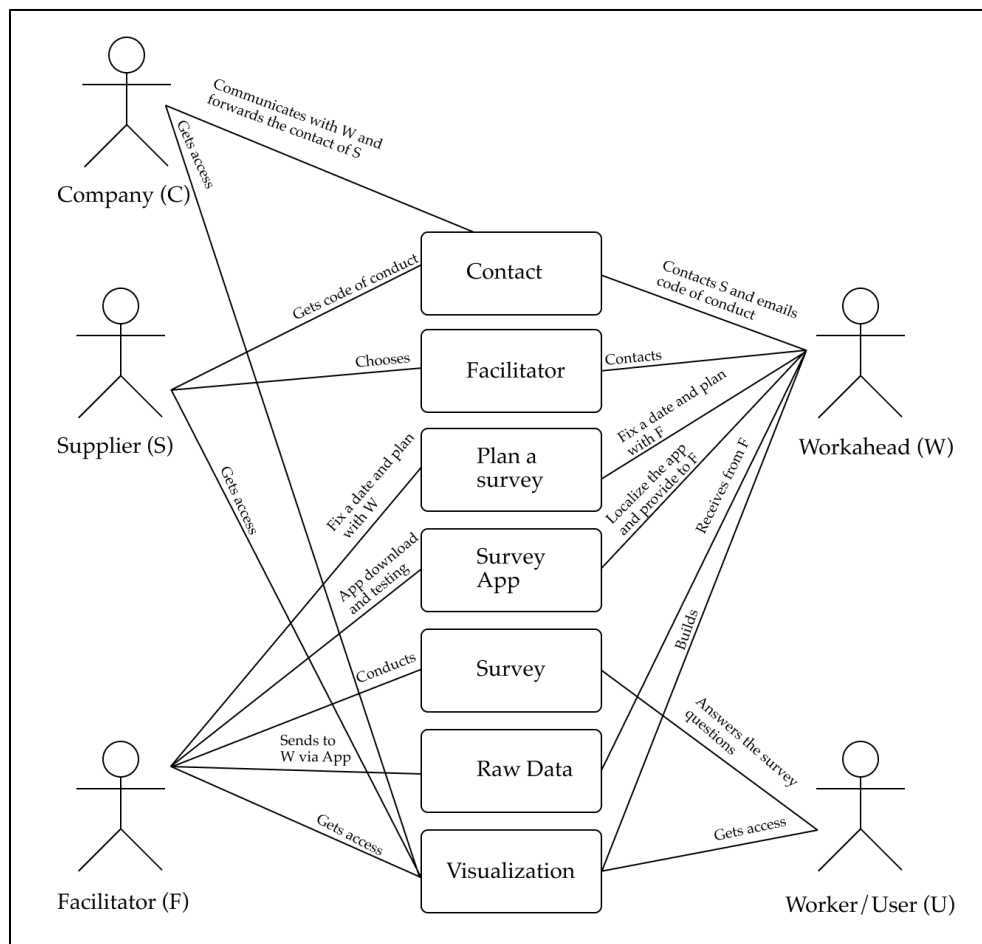


Figure 12. Use case of WorkAhead’s survey

As mentioned in Section 5.2, understanding a user journey assures the quality of the product. A use case is utilized to visualize the journey of WorkAhead's users. The journey of WorkAhead's (W) survey consists of a process between Company (C), Supplier (S), Facilitator (F) and Worker (U) as illustrated in Figure 12. Supplier is one that supplies the product to the company. Facilitator facilitates and conducts the survey to the workers of the supply chain. A facilitator has an important role in the process of WorkAhead's survey because he/she is the one who visits the site and makes the survey successful.

Firstly, either C or W initiates to have the first contact with each other. In either case, C forwards the contact details of S to W. W contacts S and provides the code of conduct as well as necessary instructions to choose F. Also, W shares examples of survey questions to S in order to establish the credibility. S chooses F and forwards to W. In collaboration with F, W plans and fixes date of the survey. For that, W localizes the app and sends the credentials needed for using the Survey app. Next, F configures the app and downloads in various phones.

On the survey data, F conducts the survey, provides information and instructions to U. U participates in the survey. After the survey, F sends all saved data through the app and W retrieves the raw data. The raw data is then visualized by W. Finally, Company, Supplier and Facilitator can get access to the visualization. However, the same visualization can be very challenging for U. Therefore, WorkAhead visualizes the raw data which can be understood by LL users. Consequently, LL users of W can also get access to the visualization. LL users who have smartphones or desktops can now access the new design of the survey report. In case of a survey in rural villages of developing countries, facilitator again visits the site and provides the design to LL users considering all LL users might not own personal devices.

5.3.2 Phase 2: Specifying user requirements

This section describes the initial interviews held in order to understand the mental models of LL users regarding simple visualization methods such as bar graphs and infographics. It also discusses observations made during the interviews. Additionally, this section presents with a storyboard created to understand the flow of the interaction between LL users and design.

5.3.2.1 Initial Interviews and Participants

In total, there were three interviews held (P1-P3). The primary goal of these interviews was to find out needs of the user and to know their familiarity towards graphs or any kind of information visualization methods. Therefore, nine graphs were shown, and questions related to graphs were asked to participants. The bar graphs were created taking design guidelines discussed in Section 3 into account. Also, “Chernoff faces” and “icon representation” in Section 4.2 are utilized to design the “Yes”, “Partially”, “No”, “I don’t know” and other icons as shown in Figure 15. They were kept as simple as possible with less text, more visuals and numbers. The data represented in the graphs does not belong to previously conducted survey. They are assumed in order to maintain the privacy of real data. All the elements in the graph such as icons and text are created in Figma design software. All the graphs used in the interviews helped in getting insights from the participants.

Graph 1 is an infographic that shows 10 icons of women and 7 icons of men. It indicates the number of people who participated in the survey. Graph 2 indicates the same information as graph1 but is visualized as a bar graph. Graph 1 and 2 are illustrated in Figure 13 and 14 respectively.

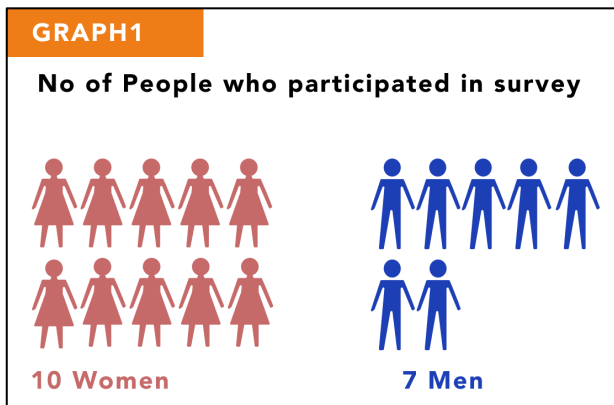


Figure 13. Graph 1

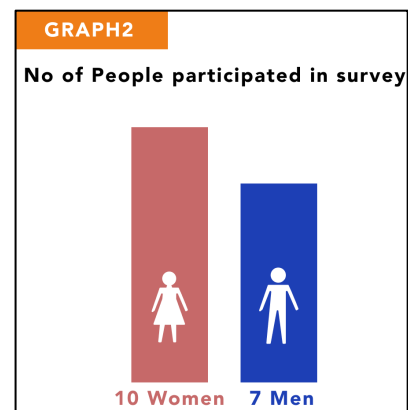


Figure 14. Graph 2

Graphs 3, 4 and 5 shown in Figure 15 illustrate the number of people who answered “Yes”, “Partially”, “No” and “I don’t know” to questions regarding food, electricity and water. All three graphs are represented as a vertical bar along with icons and numbers of responses.

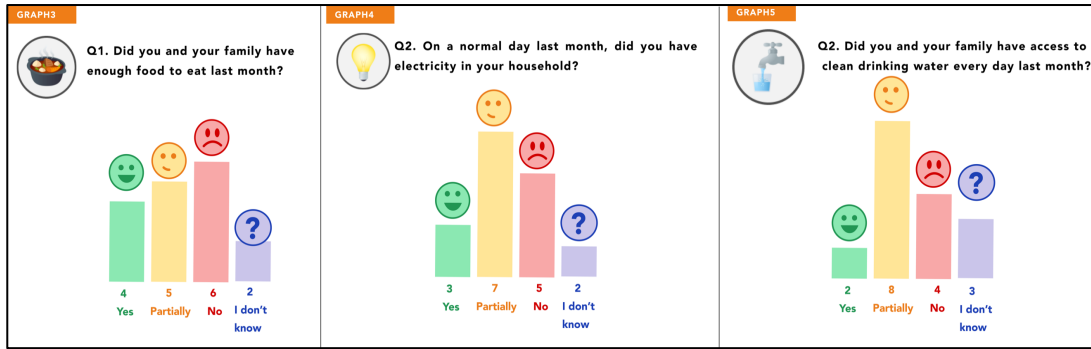


Figure 15. Graph 3, 4 and 5

Graphs 6, 7 and 8 illustrate the number of people who said “Yes”, “Partially”, “No” and “I don’t know” to questions regarding food. In Figure 16, Graph 6 represents horizontal bar, Graph 7 a vertical bar and Graph 8 a single line bar with colour coding.

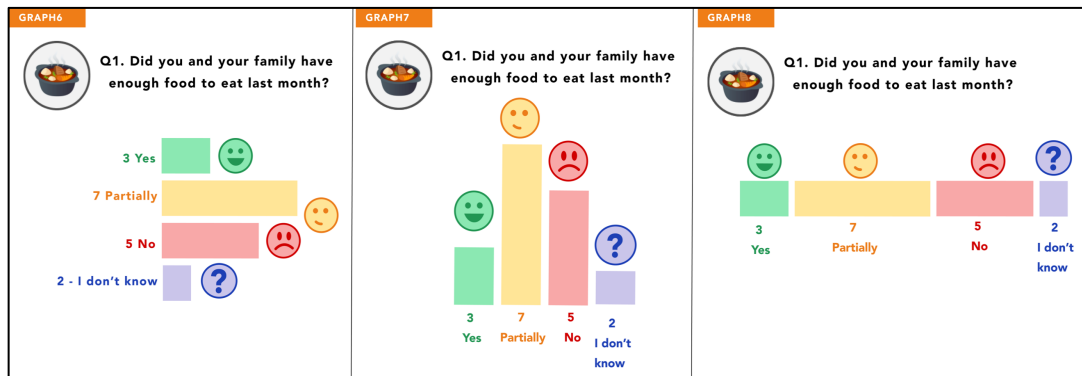


Figure 16. Graph 6, 7 and 8

Graph 9 in Figure 17 also represents bars that indicate the number of men and women with face icons. In addition, there are other regular icons that indicate age of men and women. For example, men and women icons with hand on waist represent young and active adults, and with the stick on one hand, represent elderly people. Similarly, women icon with a longer dress represents a middle-aged woman whereas shorter represents a younger woman. Finally, men icon with a bigger belly represents a middle-aged man.

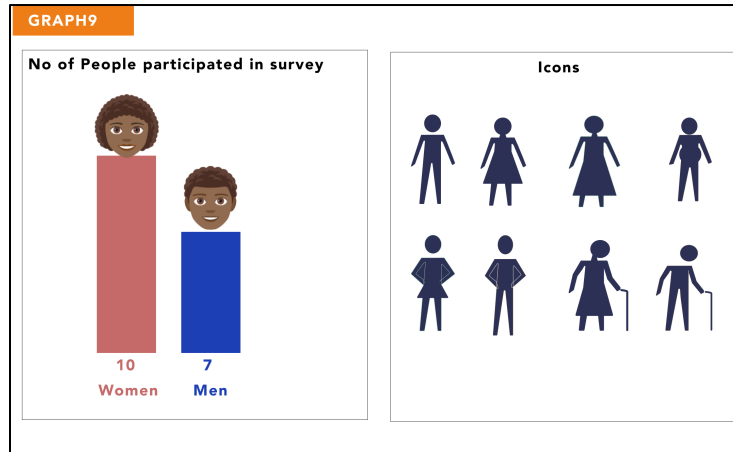


Figure 17. Graph 9

Graphs 10 and 11 were shown only to P3. Graph10 represents the number of employees divided based on age and gender. Graph 11 represents the life span of elderly men and women compared with the present and future prediction.



Figure 18. Graph 10

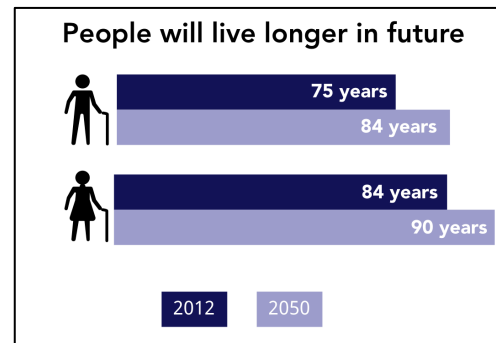


Figure 19. Graph 11

The interviews were semi-structured. An interview script was utilized to continue with the flow of the questions. The script begins with an introductory part explaining the purpose of the interview followed by questions categorized into eight segments. Segment 1 had opening questions and segment 2 dealt with questions related to Graph 1 and Graph 2. Similarly, segment 3 had questions related to Graph 3, 4 and 5. Segment 4 consisted of questions of Graph 6, 7 and 8. Segment 5 had questions related to Graph 9. Segment 6 and 7 dealt with questions related to data and visuals respectively. Finally, segment 8 had debrief questions to conclude the interview. The interview script can be found in Appendix 2.

As illustrated in Table 4, P1 and P2 are Haitian and their interviews were held in Haiti. P3 is a Nepalese who has been living in Finland from the last 6 years and his interview was held in Helsinki. All participants had a low educational

background. They could write their name and address. During I1 and I2, there was a translator who translated the whole session. In addition, I1 and I2 were video recorded interviews. Prior to these, participants were asked for consents to participate and record the interviews. In I3, the interviewer could speak the language of P3, so no translator was needed. Along with that, consent form to only participate was used as I3 was not recorded. Note taking was utilized as a method of recording.

Table 4. Information of participants

Participant	Participant 1 (P1)	Participant 2 (P2)	Participant 3 (P3)
Age	25-35	25-35	39-49
Gender	Female	Female	Male
Education	low	low	low
Nationality	Haitian	Haitian	Nepalese
Interview location	Haiti	Haiti	Finland
Interview	I1	I2	I3

5.3.2.2 Observation

P1 and P2 were shy to answer the questions. P3 seems to be slightly more comfortable as interviewer spoke his language and there was no camera involved in the interview. All participants mentioned that they were not familiar with graphs, in fact, they were seeing graphs for the first time. The level of complexity of graphs was in increasing order. Therefore, Graph 1 was easily understood by all of them. Moreover, questions starting from segment 1 led to questions in upcoming sections. However, P1 and P2 did not understand the meaning behind the bar graphs even though the interviewer kept explaining in each section.

When Graph 3 was shown to P3, he thought that the rectangles in bar graphs were doors and people were going inside the door. When asked about the difference in the size of doors (bars), he said: “the longer one is big because there are more women than men to fit inside the door”. After this, P3 understood other vertical graphs similar to graph 3. However, he did not understand the horizontal bar graph in graph 6. He, later on, managed to recognize single line bar graph of graph 8. Furthermore, P3 was also given graph 10 and 11. He was not able to understand sets of data because these graphs had 3 sets of co-related data.

Overall, all icons and numbers were easily understood by all participants. In addition, they also understood the colour coding between icons and bars. When observing their performance regarding graphs, I conclude that users first need a proper explanation of the meaning behind the graphs, before handing over. P3 could understand the only graphs which were similar to the graph explained in the beginning. Along with that, the graphs should not represent more than two sets of item or data because they are unable to relate when they see more than two information at the same place.

5.3.2.3 Storyboard

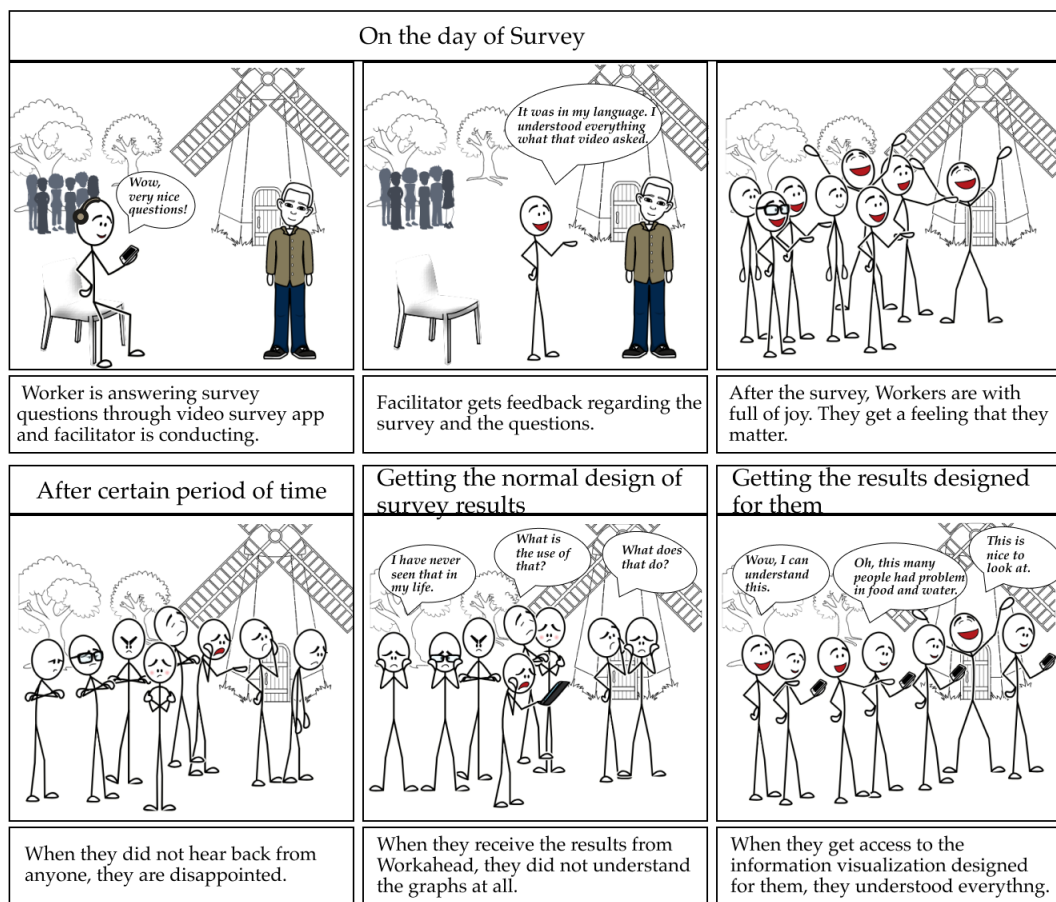


Figure 20. Storyboard of experience of Visualization

The storyboard in Figure 20 is created to provide a narrative to the use case. In addition, it is created to understand the problem and its solution. On the day of the survey, users are quite happy with the questions and experience with the survey app. After survey, users are disappointed because they did not hear back from anyone. When they actually received the results, nothing made sense to

them. Finally, when WorkAhead sends the visualization targeted for them, they understood what data showed.

This storyboard shows clear use of WorkAhead's survey app and solves the problem of WorkAhead's LL users. With the help of emotion, it visualizes UX of an entire journey when using the survey app and its data visualization. In addition, accessible visualization indicates that the design of a survey report should be made responsive. This helps the report to be accessible in any device regardless of various shapes and sizes.

5.3.3 Phase 3: Producing a design solution

The design is created based on design guidelines and best practices of visualization found in academic research and findings from initial interviews.

After the three initial interviews, I understood that LL users are not familiar with graphs and pie charts in general. During the interviews, I noticed that the static representation of data did not make sense to participants. They could not relate to numbers and how values reflect on the sizes of the bars. Therefore, the use of animation was considered as a solution to this problem. Motion brings data to life. It shows the different meaning of how numbers and space indicate the value of data. It also draws user's attention making them interested in knowing what the design is trying to show. As only similar kinds of graphs were understood by P3, only one or two types of animation are used in order to ensure learnability.

In my opinion, when visualization is made interactive, it provides freedom to interact with the survey report. LL users can have time to learn and interact with the design. They can see graphs repeatedly and try to interpret the meaning of the represented data. Along with this, to solve the issue of delivery, visualization is designed as web-based which can be accessed by LL users of WorkAhead from any part of the world. Considering the problem of mobility in rural areas of developing countries, the design is developed for a multitude of devices. This ensures the accessibility of the design to LL users of rural areas who own small displays and hand-held devices.

The survey application of WorkAhead has almost 30 to 40 questions. The questions are related to a worker's life and work conditions. However, not all of the responses to the questions are important for workers to know. Some of the

responses are very important for companies to know whereas some are for the workers. Thus, the data for LL users is formulated to show only the responses that matter and make a difference in their lives. WorkAhead analysed the questions that yield the most important responses from LL users. Hence, with the help of WorkAhead, questions are filtered, and unnecessary data are excluded.

To further ensure the simplicity in the visualization, questions are categorized according to their type. Each categorization is showed through texts and semi-abstract icons. Avoiding text was one of the design guidelines for LL users. Consequently, only little text is used which provides motivation to second level adults (Table 2) to read slowly. Based on the mentioned points in this section, an initial prototype of a design solution is made.

5.3.3.1 The Initial Prototype

The initial prototype is mainly based on an iconic representation of WorkAhead's questions and categories. The animation, icons and all elements of the prototype are built in Figma design software. This prototype allowed for some interaction within the data. When opening the prototype, the first section to appear is the home page. The home page consists of centrally arranged circles as illustrated in Figure 21. These circles allow users to navigate to see related graphs with animation.



Figure 21. Home Page of initial idea

Circles represent categories of survey questions. The circles when clicked lead to the next page where an animated graph is displayed. Some categories such as “Work” have sub-categories which open in a new page (Figure 24 a, b & c) and

the graph of subcategories open in next new page. The navigation model of the design is displayed in Figure 22.

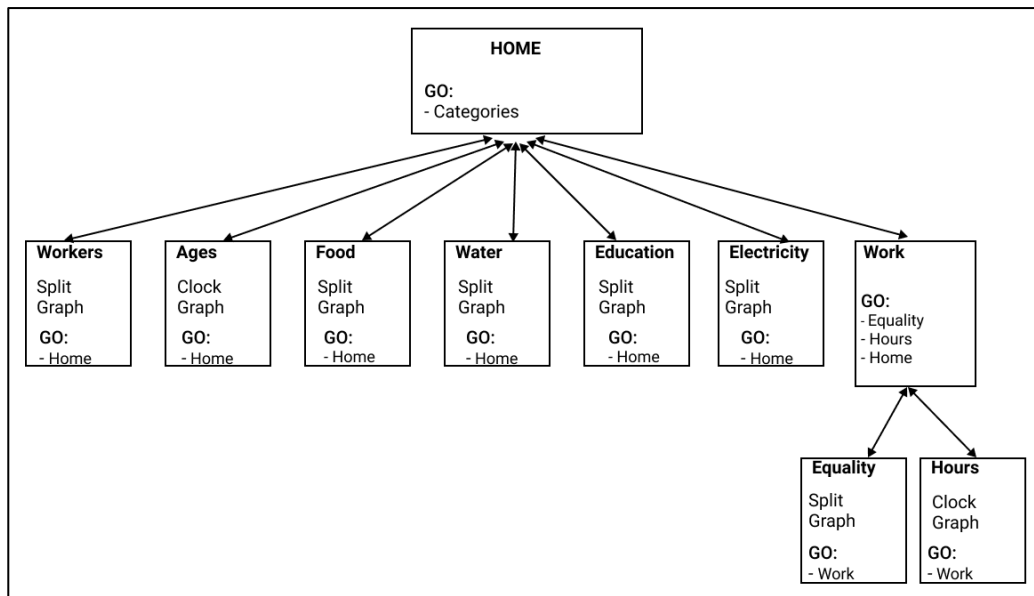


Figure 22. Navigation Model of initial prototype

There are two types of graphs embedded in the design, split graph and clock graph. Both graphs are based on the visualization techniques described in section 4.2. The split graph is derived from Mosaic plots described in Figure 6. It is demonstrated in Figure 23 which represents the data of the “Food” category. Three responses from (Yes, Partially, no) have different values encoded in their mouth expression to represent different meanings. Also, they are colour coded with the value of data. The animation pattern of a split graph is shown in Figure 23, from A to G. The frames move within the time frame rate of 500 milliseconds. When the animation stops at Figure 24.G, navigation to home page appears.

Clock graph is derived from the concept of dials from section 4.2. It is used in this design to visualize data such as “Ages” and “Hours of work”. The visualization of “Hours of work” can be seen in Figure 24c. The animation pattern of clock graph of “Ages” is shown in Figure 25, from A to K. The elements in the graph appear slowly in a clockwise direction. To display ages, icons appear clockwise starting from 0-14 years and ending with 60+ years. This indicates the time and is related to a real-world phenomenon which LL users can easily relate with. The animation happens with the frame rate of 500 milliseconds. When the animation stops at Figure 25 K, navigation to Home page gets activated.

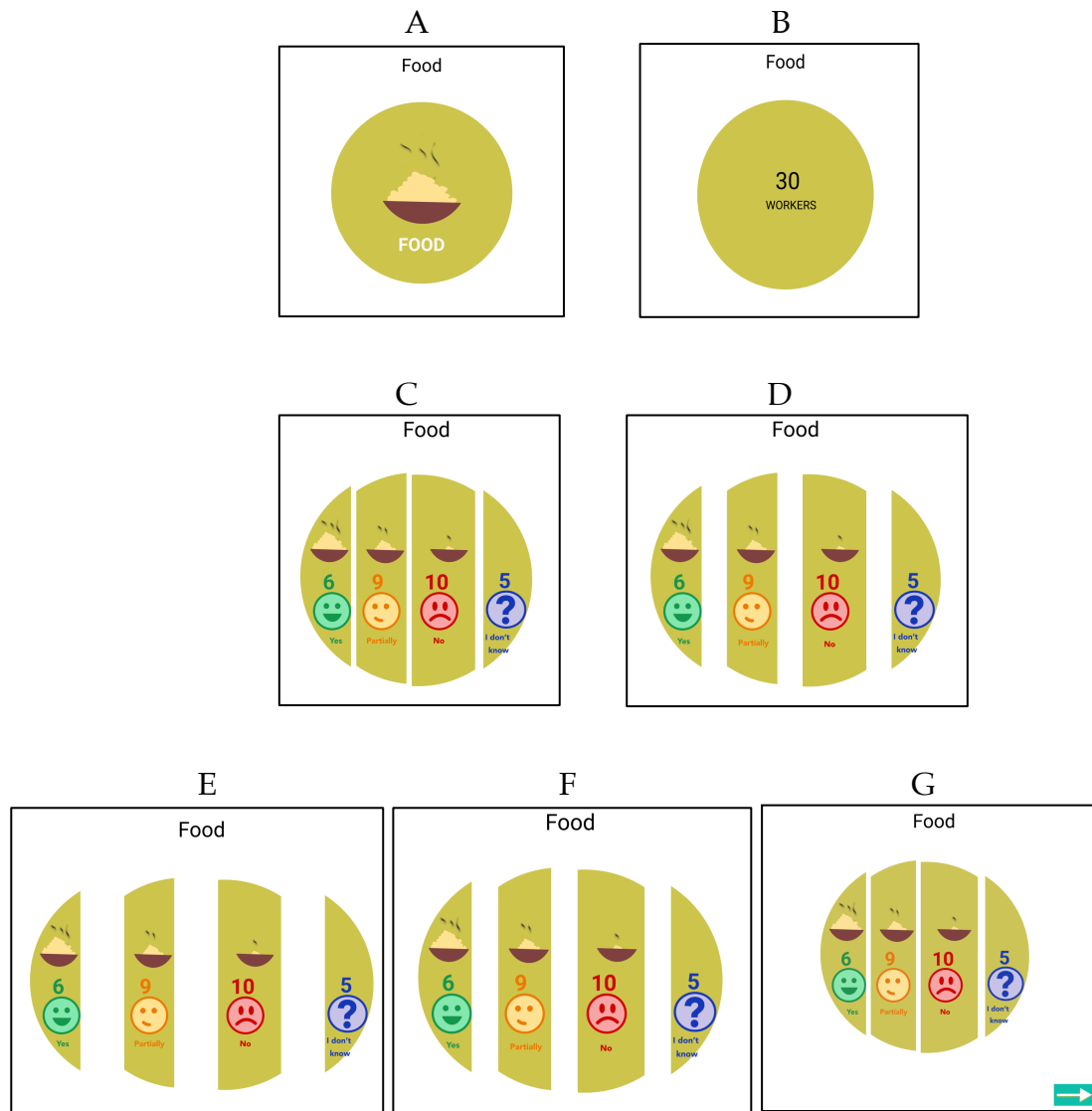


Figure 23. Split Graph animation frames from A to G in animation frame rate of 500 milliseconds

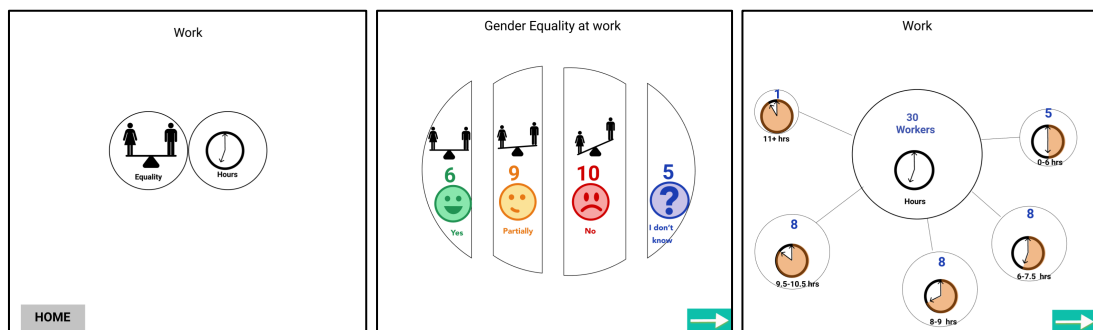


Figure 24 a (left). Work Category, Figure 24 b (middle). Graph of gender equality, Figure 24 c (right). Graph of hours of work

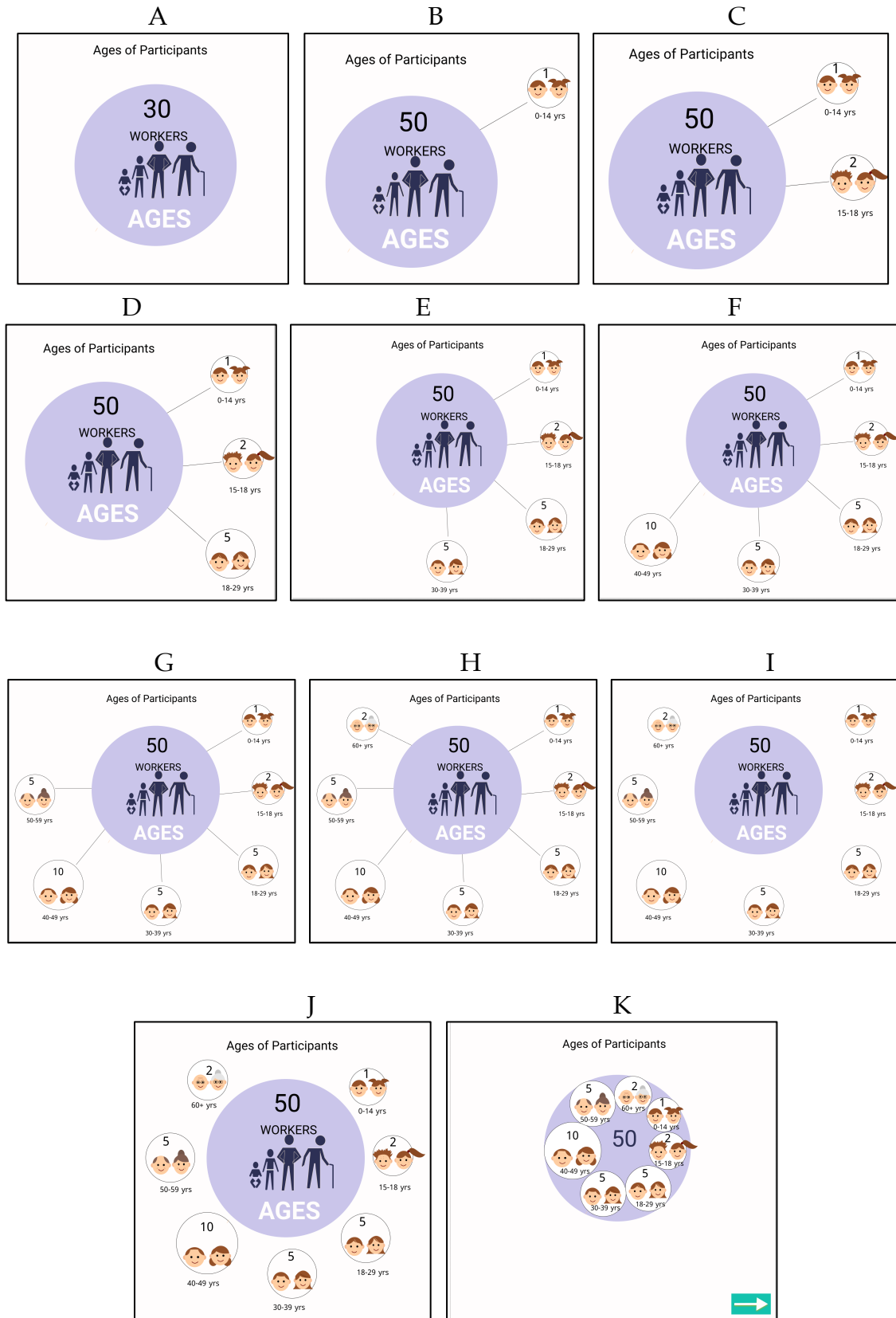


Figure 25. Clock graph animation from A to K in frame rate of 500 milli seconds

5.3.3.2 The final prototype and its implementation

The initial prototype design was improved based on observation from the initial interviews. The final prototype is a functional web application and is aimed for testing with LL participants. It is built with React application, a JavaScript library. Along with that, CSS3 is used in implementing animation and beautifying the design.

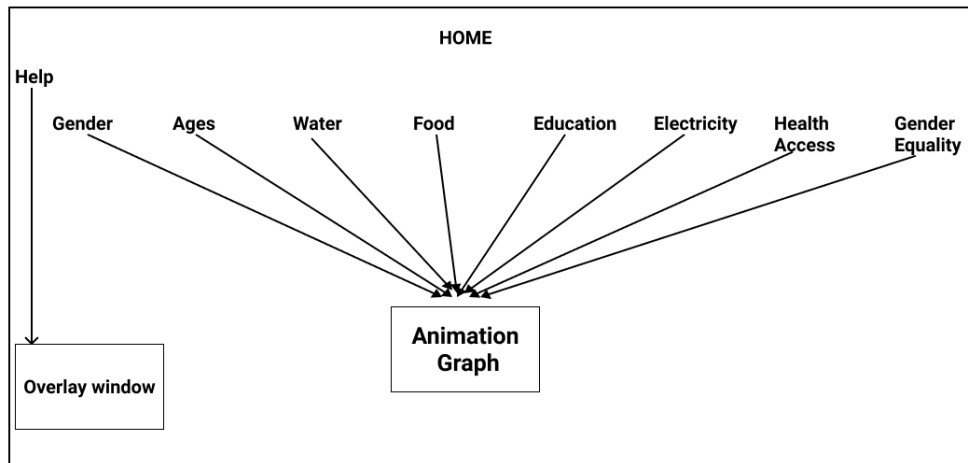


Figure 26. Improved Navigation model

I evaluated the initial prototype taking design guidelines into account. I figured that navigation is too complicated for LL users. The navigation contained hierarchical menu structures that LL users have less understanding of. Therefore, to simplify the navigation, flat navigation was implemented. The graphs now appear in a single page and can be opened with one click. The categories lie horizontally at top of the page and graphs appear on the same page below. This means that there is no new page in the final version, every interaction happens in one single page. The navigation model of the final prototype is illustrated in Figure 26. The home page with horizontal navigation is shown in Figure 27.

The circles in the graphs are replaced by rectangles with curved edge. In my opinion, the area of a circle has a negative impact on showing data. The same value of equalized split parts of circles may appear uneven and vice versa. It would be challenging for LL users to compare the data with this kind of uneven distribution of area. Therefore, split graphs are represented through rectangles as shown in Figure 30 a to c.

Help button is embedded and made accessible in every stage. The button leads to a video with localized audio that contains visuals with an explanation of the meaning of elements. To elaborate, it introduces visualization and explains how to use the design. In this design, the audio is recorded in Nepalese language, since participants were going to be of Nepalese nationality. The help button is represented through an eye and ear icon. The eye represents as seeing whereas ear as hearing. The button is located on the top left corner of the prototype. It opens in the same page as a modal window as demonstrated in Figures 28 and 29.

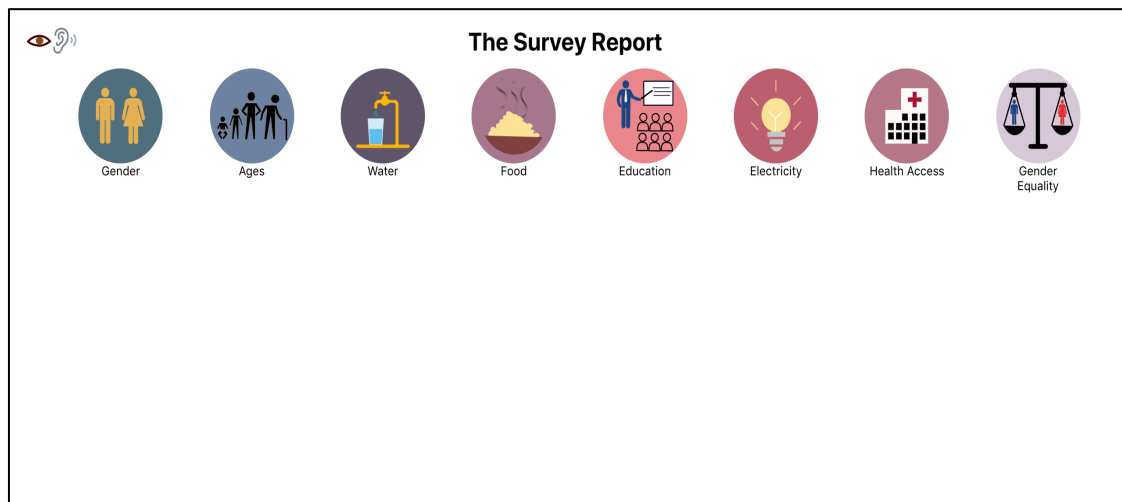


Figure 27. Home page of the final prototype

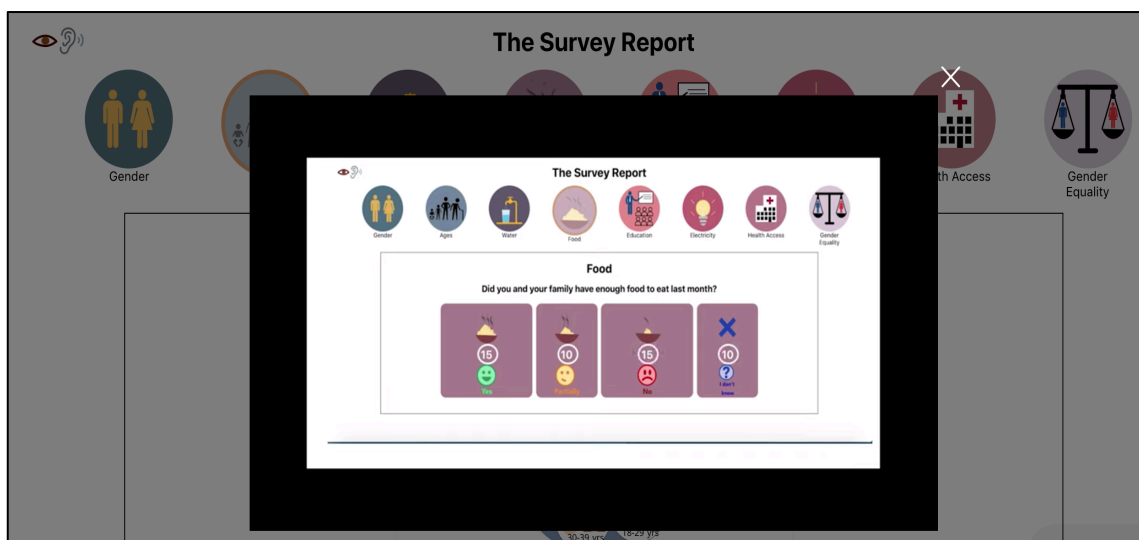


Figure 28. Modal help window. explaining the meaning of numbers in Help video (the numbers are circled)

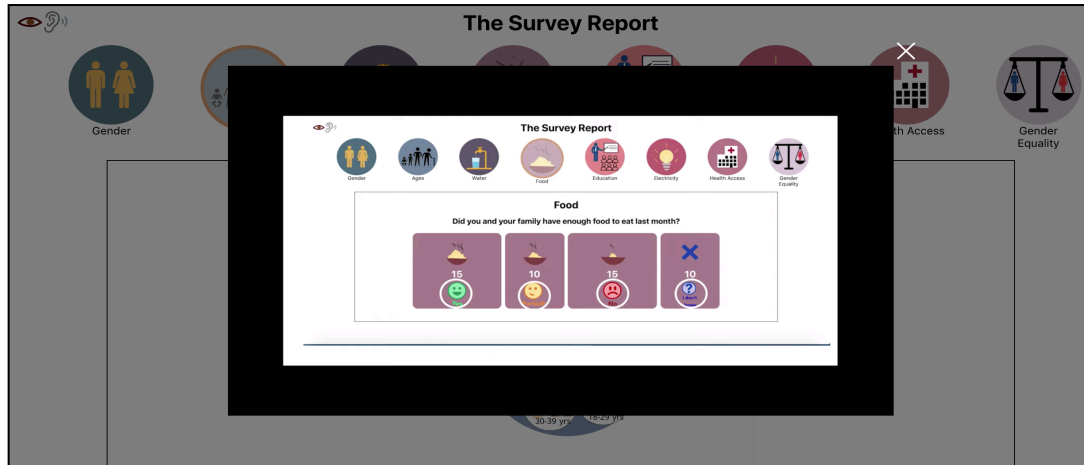


Figure 29. Modal help window. explaining the meaning of responses in Help video (the icons are circled)

To further simplify the initial prototype, I further filtered the data to make it as simple as possible. I excluded less important information and included more useful one. The icons are also further simplified and made less abstract.

To promote the visibility and comparability of data, size of icons is implemented as relative to the value of data. This means that icon that represents bigger value will appear bigger than the icon that represents small value and vice versa. For better UX, the transition in the animation is made smooth. The animation frame rate is of 500 milliseconds. I embedded a hover effect in the navigation to indicate that circles are clickable. In addition, I made current navigation visible to indicate the current status of the system.

The three frames of animation in the functional prototype are shown from Figure 30a to 30c. They illustrate information about the category called “Food” in three stages. The first stage displays category icon, second displays total number of participants, and the third displays split responses.

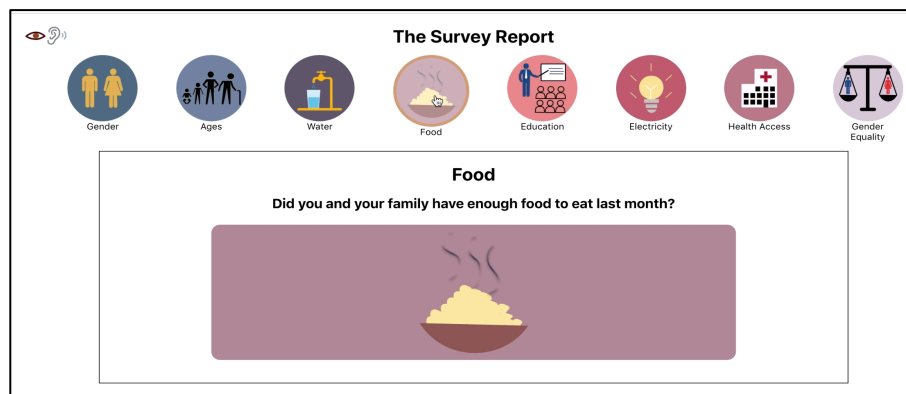


Figure 30 a. Step 1 of split graph of Food category



Figure 30 b. Step 2 of split graph of Food category

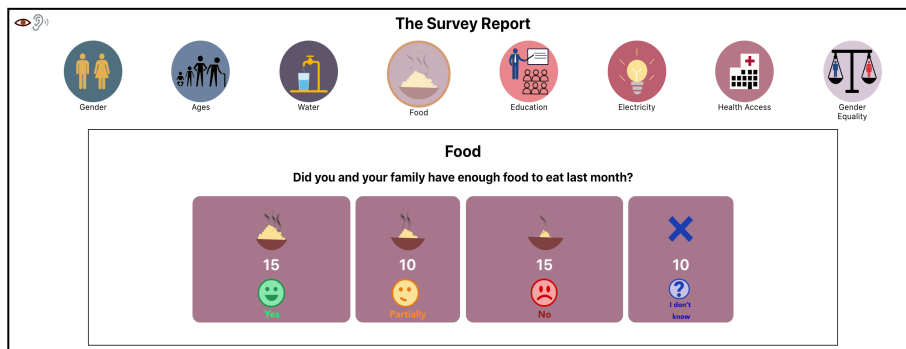


Figure 30 c. Step 3 of split graph of Food category

In my opinion, the clock graph shown in Figure 25 is more complicated for LL users because it consists of more than two numbers in the same circle. Therefore, in the final prototype, clock graph is embedded only in one category called “Ages”. The meaning of clock graphs is also not explained in help feature. The main goal of keeping the clock graph in only one category was to actually test it with LL participants and find out whether it makes sense to LL participants or not.

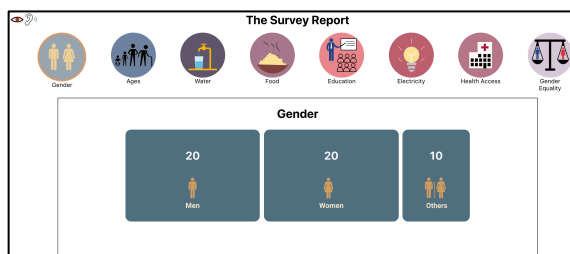


Figure 31. Gender Graph

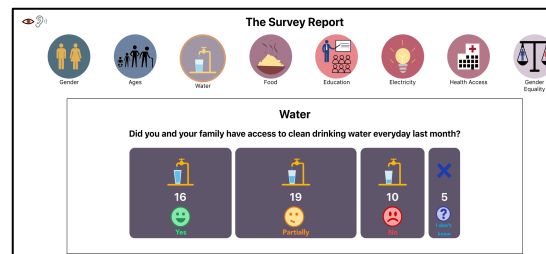


Figure 32. Water Graph

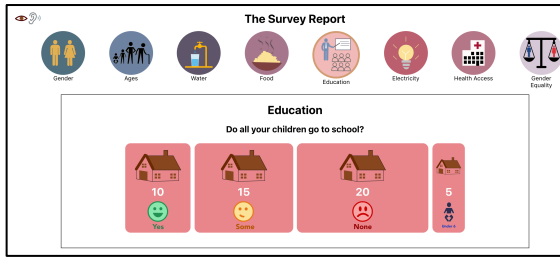


Figure 33. Education Graph

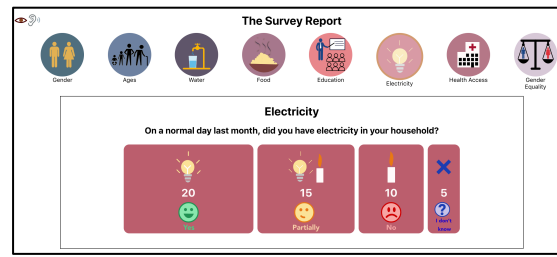


Figure 34. Electricity Graph



Figure 35. Health Graph

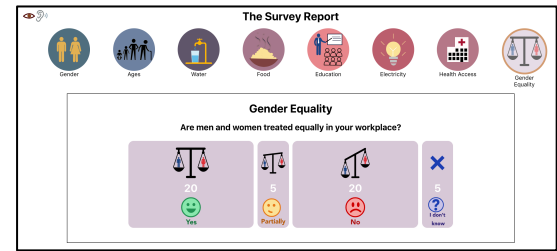


Figure 36. Gender Equality Graph

Except “Ages”, all other categories are visualized by using split graph animation. Categories such as “Gender”, “Water”, “Education”, “Electricity”, “Health Access” and “Equality” are illustrated in Figures 31, 32, 33, 34, 35 and 36 respectively.

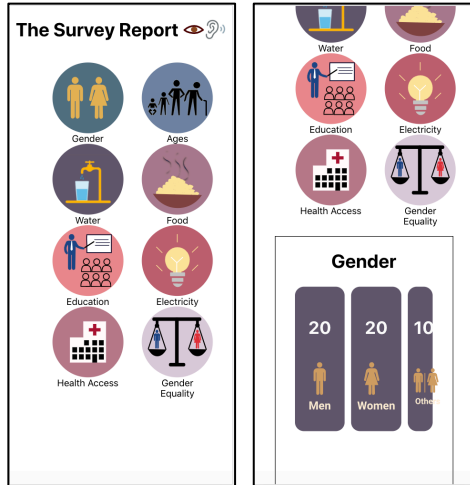


Figure 37 a and b. Home page and Gender graph in iPhone X version in portrait

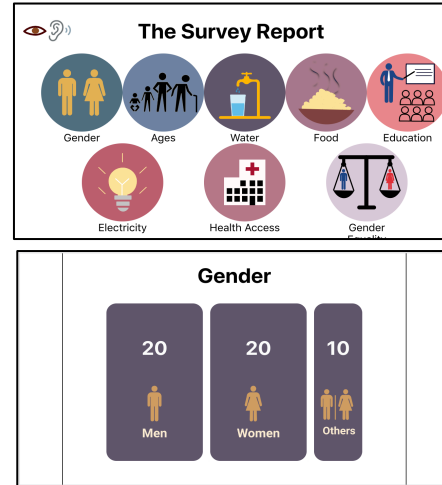


Figure 38 a and b. Home page and Gender graph in Samsung Galaxy S5 in landscape

As the prototype is made responsive, it adapts in the size and orientation of the screen. Figure 37 a and b display the final prototype in iPhone X version in portrait orientation whereas Figure 38 a and b in Samsung Galaxy S5 version in landscape orientation.

6. Evaluation against user requirements (Phase 4)

This chapter consists of three sections. The first section presents the interview process and background information of participants. The second section discusses the results of interview and the third describes the interpretation of interview results.

6.1 Interviews and Participants

To evaluate the final prototype, six participants were interviewed. The design was tested on a laptop computer. In my opinion, most of LL population are most likely to own a smartphone. On the other hand, they are less likely to own a laptop or a desktop. So, the idea of testing on a laptop was to evaluate the interface in a device where LL users are not familiar with. In my view, this yields the most honest responses from participants regarding design. When one is not so familiar with the device itself, he/she is more likely to confuse and may not hesitate to ask. This can help in finding raw opinions.

The primary goal of testing the prototype was to examine whether the visualization makes sense to LL participants or not. The secondary goal was to check if the features of the interface are helpful in making data understandable. An interview script was followed to maintain the flow of the session. The interview script also included task questions that were read to the participants. During interviews, screen and audio were recorded as a form of note-taking. Prior to these interviews, consent was asked for participating and recording. In addition, a background questionnaire was also used to gather the background of participants. The consent form was signed by participants whereas the background questionnaire was filled by the interviewer. The consent form, background questionnaire and interview script are attached as Appendix 3, 4 and 5 respectively.

The testing session included allowing participants to use the design and asking questions regarding the prototype. The concept and goals of the design were explained in detail at the beginning. Participants were asked to watch and listen to a “help” video. Next, they were asked to see the graphs. Then, task questions regarding the graphs were asked. During the session, if participants got confused with the graphs, they were suggested to watch the “help” video again. At the end

of the session, there were a few general questions regarding their thoughts and feelings on the design.

Table 5. Information of the participants

Participant	P1	P2	P3	P4	P3	P6
Age	32-39	32-39	22-29	22-29	39-49	39-49
Gender	Male	Female	Female	Male	Male	Male
Education	7 th grade	5 th grade	Less than 3 rd grade	Less than 3 rd grade	Less than 3 rd grade	Less than 3 rd grade
Nationality	Nepal	Nepal	Nepal	Nepal	Nepal	Nepal
Interview Location	Finland	Finland	Nepal	Nepal	Nepal	Nepal
Interview	I1	I2	I3	I4	I5	I6

P1 has an education level of 7th grade, P2 has 5th grade and other remaining participants have lower than 3rd grade. When comparing the adult literacy level based on Table 2 and 3 from Section 2, P1 falls under the second level and Level 2. He could understand a few letters of English. However, he could not read complex sentences. He could read and write slowly in his native language.

Similarly, all participants from P2 to P6 fall under First Level Adults in adult literacy levels based on Table 2. They could not speak or read English. They could read simple and short words and letters of their native language. All the participants are daily smartphone users, but they are not familiar with using a laptop and mouse. They were taught how to use these devices before starting the session.

6.2 Results

Split graphs were understood by five out of six participants. All participants had a hard time understanding them in the beginning. When they were asked to use the help video again, all understood split graphs and were able to answer the questions regarding each graph. All participants understood the data and meaning behind most of the icons. The emotions expressed by icons were easily predictable to participants as their meanings were clearly explained in the help video.

Clock graph shown in Figure 25 was understood by only one participant. P4 understood the clockwise phenomenon of showing ages, he commented, "This is so cool". When asked about the total number of people from age 0-14, P5 answered " $2+14=16$ ". P1 understood the graph as 2-14, 3-18 and vice versa. They confused the numbers and years because clock graph consists of 2 sets of data.

Almost all participants were confused with others (gender) icon shown in Gender graph in Figure 31. In addition, under 6 (baby icon) shown in Electricity graph in Figure 33, was also not understood by five participants. Along with that, there was confusion in between "NO" and "I don't know" icons. The meaning of a cross in Nepal also means no. Therefore, five out of six participants were mixing answers of both responses.

Some of the participants anticipated the interview session to be complicated. They assumed that answers to the asked questions were much more complicated than what they were seeing on screen. Therefore, they started to add or subtract one value of data with another. Furthermore, when asked about the total number of participants in the survey, five participants did not immediately have an answer to this question. Despite being explained several times, such as in the introduction segment and help video and also in animation, they would start counting values in split graph to get the total number of participants.

At the end of the interview, participants commented on some features that they liked and disliked. Some liked the animation of a split graph whereas some liked the animation of the clock graph. "I liked the moving graph even though I did not understand it. It is nice to look at", commented P5. Some gave feedback to the design. P3 commented, "The way of showing the graph is ok but I would understand easily if someone would explain to me all the graphs one by one".

6.3 Findings

The aim of this section is to interpret and analyse the results of the interviews presented in Section 6.2. The analysis is done to identify improvements in the final prototype. To ensure not to miss all thoughts and comments of participants, recordings were watched. The results of the interviews indicate that the final prototype has room for improvement. As this study is based on an iterative process, it should be further iterated into an improved version with the implementation of points discussed in this section.

Participants did not know how many survey participants were in total, regardless of explaining several times. Some participants even started adding numbers by themselves. This indicates that animation is not all-time an ideal way to visualize. It should be done carefully in case of LL users. The important elements should be visible and not hidden in the animation.

Conversely, the fact that participants were adding to answer the question of the total number of people verifies that they understood the idea of split graph animation. The reason why they could not remember the total number is because it was hidden. This proves that the idea of a split graph and its animation made sense to LL participants.

Furthermore, the colour coded icons were remembered easily because of the colours and their emotions. On the contrary, confusion between “No” and “I don’t know” icon proves that similar types of icons should not be used for interpreting the different meaning of responses (Figure 30c to 36). In my opinion, the cross icon showing the meaning of “I don’t know” should be replaced with another appropriate icon. Similarly, icons such as “under 6” in Education graph (Figure 33) and “others” in Gender graph (Figure 31) should be replaced. Additionally, all icons should be made bigger than what normal eyes can see, to ensure visibility. The icons (Figure 33) were relative to the value of data, icons with smaller value appeared smaller than normal size, which made it difficult for LL participants to understand. Therefore, icons should not be implemented relative to the value of data.

Moreover, all icons in the design were more or less placed in the same place. For example, “Yes”, “Partially”, “No” and “I don’t know” icons, the category icons, and numbers were inside area of split parts of the rectangle (Figure 30 c). Due to this, LL participants were noticed to take more time than expected to understand the data. Hence, some of the icons should be placed outside the rectangle.

During interviews, some of the questions had to be repeated several times to make them understand. Therefore, the questions in the interview should be simple and short. In addition, help video had to be played several times in order to check the meaning of graphs from time to time. This also indicates that help video should have a very slow and clear explanation with the use of simple words. In my opinion, the availability of help video from every stage of the design was successful as LL participants were able to access it easily.

Split graphs were more or less understood because it was explained in the video and there were more examples of it. This proves that similar kind of graphs should be used in order to promote learnability as well as understandability. On the other hand, clock graph was very confusing because there were two sets of data aligned in the same place. In my opinion, the alignment of icons and numbers also confused participants. Thus, visualizing two sets of data should be done with extra conscientiousness.

7. Discussion

The new information age has profoundly changed people's way of thinking and communicating. It has made people's lives easier by transforming a large amount of data into a visual format. However, LL users are still not considered as potential users of information visualization.

There has been research focused towards LL users, regarding designing mobile applications, information search, and other similar technologies in general. This study, however, focused on studying understandable information visualization techniques that can be accessible to LL users. This aspect of the study has not been studied as widely, which required adapting and comprehending the existing research into a new field. However, general design guidelines for LL users found in previous research were utilized to generate the final prototype. In addition, the final prototype is also based on findings from user research done during the design development process.

The study focused on visualizing WorkAhead's survey data. WorkAhead surveys workers of enterprises in the supply chain. It uses video surveying application that collects responses of workers. WorkAhead has its own design standards of visualizing their data. The final prototype created in this study, however, did not use WorkAhead's design standards. The design standards of WorkAhead are not accessible for LL users. Therefore, the design standards used in this study are based only on design guidelines from previous research.

Testing a prototype requires participants that fall under the targeted user group, which may affect the outcome of the test. In this study, finding right kinds of participants posed certain difficulties. Searching for LL participants in Finland was challenging and time-consuming. Therefore, most of the interviews were done outside Finland. Additionally, it is considered impolite to ask the level of education and background of a LL person. LL people are already insecure about their literacy skills and being asked about that may induce a negative effect. Thus, there were some challenges in how to approach and ask their consent for participating in testing and interview.

The testing situation consist of obstacles which need to be considered beforehand. In this study, as the final prototype was not hosted on a public server, participants were not able to access, through the internet. A tool was used

to expose local development server to the internet which was not as fast as it would be with a public server. Due to this, the link kept breaking from time to time and it needed to be restarted. This caused a distraction to participants. In future, the testing should be done using better alternatives that do not cause such kind of disruptions.

Due to diversity in mentality and thought process, working with LL participants is an intricate task. Most of the time, they would start talking about different matters in the interviews. Also, many task questions had to be repeated several times. Therefore, it is important to make sure the questions are simple and have familiar terminologies used to yield the most honest opinions.

Information visualization is a method utilized since early period such as cave paintings. Kirk Andy (2016) stated that current dominant methods of visualization are bar, line, and pie charts. They are being used since they were originated in the 18th century. However, LL participants had no idea regarding these methods in general. Despite some participants had been living in Finland for the last six years, they had never seen these kinds of graphs in their life. All participants were smartphone users. Simple graphs like bar and pie charts can be seen through various media such as the internet, publishing, advertising and social media. This shows that LL population tend not to notice the unfamiliar visuals around them.

All in all, the results of the prototype testing showed that split graphs were understood, mostly because of the help video with localised audio. However, there was still room for improvements such as not hiding elements in the animation, preventing the use of similar icons for interpreting different meanings, and removing the icon's size relative to the value of data. As this study focused on visualizing data of WorkAhead, there are some limitations to it. The iconic representation of design is reliable for only WorkAhead's survey report. On the other hand, the idea of split animation can be utilized in representing data of any kind. The process in this study also can be utilized as a guideline for other research on information visualization that targets LL users.

This study was advantageous to WorkAhead and the design of the final prototype will be used to develop an app further. LL users of WorkAhead play a vital role in solving WorkAhead's sustainability development goals. Hence, it was important to target LL users and consider their requirements. In addition to

the literature review, it was beneficial to interview some users of that target group. The testing of the final prototype confirmed that participants understood split graph animation. This indicates that an interactive design is helpful for LL users of WorkAhead to understand survey data.

As the study involved lots of iterations, the next phase is to iterate the final prototype based on the findings of the testing. After the iterations, the new version should be tested again. This time test users should come from rural parts of developing countries. This study involved low literate users who lived in urban areas and who are somewhat exposed to technology. The next version should be tested with the real workers of WorkAhead to whom the information visualization would benefit.

WorkAhead's survey is a mobile application. The design is made to be responsive so that it is accessible to users from rural areas of developing countries. However, the testing was done in the desktop version. LL users are less likely to own a laptop or a desktop. This study focused on how to make the design understandable to users. So, it was important to yield the most honest responses from participants regarding the design. Therefore, the desktop version was used instead of a mobile version. The mobile version often is different from the desktop version and all findings of this study may not be compatible with mobile devices. Future work should involve testing in mobile version and iterating accordingly.

To make the purpose of the interview and testing successful, qualitative responses are needed. Qualitative responses are needed from a variety of users, observing the behaviours, expressions, and most importantly their qualitative feedback. The initial interviews in this study involved interviews in Haiti where the interviewer was asking questions in English and translator was translating to Haitian Creole. This caused a lot of distractions and participants were not comfortable to participate. This affected in responses and not much of insights were collected. Later, in the testing of the final prototype, only Nepali language was used to interview Nepalese participants. This helped participants to respond comfortably and express in a more descriptive way. Due to this reason, the effect of the language of participants should be taken into consideration in future work.

The final prototype created in this study is based on the literature review and most importantly, on the findings from testing with focused users. This means

that the idea of visualization is mostly done from listening to the users and design from the literature review. Thus, there is a clear research gap on what methods of information visualization are LL users familiar with. The issue to study further is what are the obstacles that prevent LL users to get familiar with information visualization methods even though some methods do not require high literacy skills.

This study has new findings on how LL users can use interactive visualization with the use of a help audio-video feature. It also corresponds to previous research on design guidelines for LL users. Despite the limitations, this study meets the objectives of all the research questions. The findings proved that interactive visualization along with the use of animation makes data understandable for LL users, which answered the first research question. Likewise, the second research question is answered by implementing the behaviour of design as responsive. This means that design is compatible with any kind of devices regardless of different shapes, sizes, and is accessible to all parts of the world, even in rural areas of developing countries.

8. Conclusion

This study has focused on how to build accessible information visualization for LL users of WorkAhead. This study aimed at a complete UX design process based on the human centred design approach. The design is based on the literature review and findings from initial interviews with LL participants. The design is implemented to a functional prototype and further tested to identify improvements.

Existing research has recommendations regarding design guidelines for mobile applications, information search and other similar technologies. The aspect of information visualization for LL users, however, has not been studied as widely. This study gathered guidelines and visualization techniques found in existing research that corresponded to the requirements of LL user. Utilizing these facts and findings from interviews, a functional prototype is created.

The first research question of this study was how to visualize WorkAhead's survey report into illustrative graphics so that it is understandable to the people who lack literacy skills whereas second research question was the medium of delivery of the report. To meet these objectives, several interviews, design guidelines and visualization techniques were followed. The final prototype was then tested with six LL participants. There were two types of graphs embedded in the design: split graph and clock graph. Among these two, split graph made sense to the participants. Thus, the findings proved that interactive visualization along with the use of animation makes data understandable for LL users. This met the objective of the first research question. Similarly, implementing the design as web-based and making it responsive met the objective of the second research question. This indicates that the design is compatible with any kind of devices regardless of different shapes, sizes, and is accessible to all parts of the world, even in rural areas of developing countries.

On the other hand, there are some limitations to the final prototype. The mobile version of the design was not tested with participants and as a result, the current findings may not be compatible with mobile devices. The design requires an internet connection which in some cases may not be accessible to all rural areas of developing countries. The data and connection issues may create disruptions. Furthermore, the iconic representations of design are reliable for only WorkAhead's survey report. In addition, the design itself has room for

improvements. The hidden elements in the animation and some confusing icons should be redesigned. The idea of split animation, however, can be utilized in representing data in other research that target LL users. To add more, findings of this study can be utilized as guidelines for other research on information visualization that targets LL users.

The final prototype in this study should not be considered as a final design solution. This study is an iterative process and next phase deals with as many iterations as possible until user requirements are met. Along with that, the mobile version should also be tested and further developed. Thus, future work can involve focusing on the mobile version of the design. Consequently, future studies in this field are still necessary. Variety in methods of accessible information visualization for LL users would provide designers to have multiple design solutions and ensure supporting diversity of LL users. In future studies, the obstacles preventing LL users for getting familiar with information visualization methods can be studied and examined. Thus, more research on LL users should be conducted taking account their behaviour, characteristics, and motivation in general.

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Appendices

Appendix 1: Consent form of Initial interview

CONSENT TO RECORD INTERVIEW

We ask you to participate in an interview which is a part of our company's research process which will lead to improve our company's way of visualising data for our survey participants. By participating you will help us to know how normal/general data is interpreted, and what things should be taken into consideration while visualising the data.

We would like to record the interview. The recorded video material will only be used to help with our note taking. Your name will not be associated with the recording or with any of the paperwork that we fill out during today's session. In addition, the recording will not be shared or sent through any internet or cloud-based system to prevent possible leaks. We understand that your privacy is important for you and we want you to be sure that what you do here today will not be watched by anyone that does not have the need to watch it.

By signing this form, you will accept the above terms.

Date and place:

Signature:

Name:

Appendix 2: Initial Interview Script

INTERVIEW SCRIPT

Thank you for agreeing to participate in this interview today. I will be interviewing you and I will also be taking notes, during our session.

I am from a company called WorkAhead. WorkAhead is a company that helps enterprises to interact with their workers in the supply chain. The purpose of this interview is to learn about how our users interpret data collected from the survey. This will lead us to visualize data in a certain way that it is understandable and accessible to our survey participants. Therefore, your views are important for us. I would like to ask you some questions about the graphs that I will give you in a while. Your thoughts will help us in our research to find the best solution in the future.

Our interview will last around 20 to 25 minutes. I would like to ask for your permission to record this interview. The recorded video material will only be used to help with our note taking. Your name will not be associated with the recording or with any of the paperwork that we fill out during today's session. In addition, the recording will not be shared or sent through any internet or cloud-based system to prevent possible leaks. We understand that your privacy is important to you and we want you to be sure that what you do here today will not be watched by anyone that does not have the need to watch it.

There will be no negative consequences for stopping the interview, and it is very important for you to know that you have the power to stop the session if you feel it to be necessary.

Now, I ask a written permission from you to participate in the test that is recorded on video. Do you have some question at this point?

➔ *Hand the consent form*

(After signing the forms) Now, I will begin the interview. *(Start recording)*

Segment 1: Opening questions

(In this segment, we want to make people comfortable and get to know about what we are really going to ask in the next segments)

1. Can you tell me a little bit about yourself?
2. How familiar would you say you are with graphs and data?

Segment 2: GRAPH1 and GRAPH2

(In this segment, we want people to look at the 2 demographics and make them understand what the graph is projecting. We have to see how they understand the graph. We want to know which of the graphs make sense to them. We want to know which kind of visualization they prefer. Also, this segment will help participants to lead to answer about the bar graphs in the next segment.)

We have surveyed people before, and we have collected some data. Here, I have some graphs that represent the data of our previous survey.

➔ *(Hand the GRAPH1)*

I want you to look at this graph first.

- Can you explain to me what this graph is about?
(If not clear. Explain what the graph is about.)
- How many men and women do you think participated in the survey?

Now here is another graph.

➔ *Hand the GRAPH2*

- What do you think this bar graph shows?
- What style do you prefer most? Why?
- What part of the graphs you did not like? Why?

Segment 3: GRAPH3, GRAPH4 AND GRAPH5 (interpreting)

(In this segment, we want to know what and how they interpret the data presented in bar graph. do they understand completely what data is the graph presenting? We want to know how their mind processes when it comes to bar graph and data.)

Again, here we have 3 similar graphs. These graphs contain the information about the same people from the previous graphs who participated in our survey.

➔ *Hand the GRAPH3, GRAPH4 AND GRAPH5*

- Can you explain what do you understand from the graphs?
- What part confuses you the most? What part is not so clear?
- What part of the graphs you feel is not right?

Segment 4: GRAPH6, GRAPH7 AND GRAPH8

(In this segment, we want to know which form/style of the graphs is easily understandable. We also want to know can they really figure out the similarities of the graph. Can they understand that the only different in these 3 graphs is the style?)

Again, we have 3 graphs here. They are different from each other.

➔ Hand the GRAPH6, GRAPH7 AND GRAPH8

- Can you explain what these graphs mean? (Follow up: why do you think that icon or symbol or any graphic is about....?)
- Which of the graph makes more sense to you? Why?
- Which of the graph do you find the most appealing? Why?
- Which one is unclear and confusing? Why?

Segment 5: GRAPH9

(In this segment, we want to know if they understand the various semi-abstract and abstract icons. We want to know if understand demographic with concrete faces or just with semi-abstract icons of people.)

Now, I have the last visuals to show you.

➔ Hand the GRAPH9

- What do you think of this graph here?
- Do you prefer the icons with face in this graph or icons in GRAPH2? (**show the GRAPH2**).
- Can you explain what these icons mean? (ask about the icons one by one. Follow up: why do you think that icon means...)
- How do you think you can use these graphs?
- What would you improve in the graphs if you want to? Why?

Segment 6: Data

(In this segment, we want to know how people feel about data in general. We also want to know if people trust the data and if they trust what makes them believe in the data.)

- How often do you come across this kind of data? (Follow up: where have you seen them before?)
- What do you feel about seeing the graphs?
- In what way do you find them useful and helpful?
- Do you think this data is true? What makes you trust this data?
- How do you think this data might help someone?

Segment 7: Graphics/Visuals

(In this segment, we want to know what elements of the graphics they are attracted to. We want to know do they like this kind of attractive elements while visualising the data. Also, do they feel that graphics help understanding the data.)

- What things do you generally like in this kind of graphs? Why?
- What things about the graphs were you most attracted to? Why?

- What colour is your most favourite in the given graphs?
- In what form you think is the easiest for you to read this kind of graphics? For example, through mobile or paper or computer or any other device.

Segment 8: Debriefing

(In this segment, we want to wrap up by asking some questions if they want to still share their thoughts.)

1. Do you have some thoughts or comments that you would like to share?
2. Do you still have some questions?
3. Is there anything you would like to say at the end?

Thank you very much for taking your time. In the name of WorkAhead, I want to thank you for your commitment to this interview. Thank you.

Appendix 3: Background Questionnaire

BACKGROUND INFORMATION

Age: _____

Gender: ☐ Male ☐ Female ☐ Other

Nationality: _____

Education (Elementary school)

☐ No

If Yes: ☐ 1st grade
☐ 2nd grade
☐ 3rd grade
☐ 4th grade
☐ Else:

Appendix 4: Consent form of audio and screen recording

CONSENT TO RECORD INTERVIEW

We ask you to participate in an interview which is a part of our company's research process which will lead to improve our company's way of visualizing data for our survey participants. By participating you will help us to know how normal/general data is interpreted, and what things should be taken into consideration while visualizing the data.

We would like to record the screen of the interface that you will be using. Along with that, we will record audio of the interview. The recorded materials will only be used to help with our note taking. Your name will not be associated with the recording or with any of the paperwork that we fill out during today's session. In addition, the recording will not be shared or sent through any internet or cloud-based system to prevent possible leaks. We understand that your privacy is important for you and we want you to be sure that what you do here today will not be watched by anyone that does not have the need to watch it.

By signing this form, you will accept the above terms.

Date and place:

Signature:

Name:

Appendix 5: The prototype testing and interview script

THE PROTOTYPE TESTING AND INTERVIEW SCRIPT

The link to the design: <https://my-design.localtunnel.me/>

First make sure that you are testing this design only one participant at a time. Because this will ensure to get the honest opinions from the participants. (to avoid the influence of answers of participants)

Thank you for agreeing to participate in this interview today. I will be interviewing you and I will also be taking notes, during our session.

I am from a company called WorkAhead. WorkAhead is a company that helps enterprises to interact with their workers in the supply chain. The purpose of this interview is to learn about how our users interpret data collected from the survey. This will lead us to visualize data in a certain way that it is understandable and accessible to our survey participants. Therefore, your views are important for us. I would like to show you the design I have created and ask you some questions regarding it. Your thoughts will help us in our research to find the best solution in the future.

Our interview will last around 20 to 25 minutes. I would like to ask for your permission to record the audio and screen of this interview. The recorded video materials will only be used to help with our note taking. Your name will not be associated with the recording or with any of the paperwork that we fill out during today's session. In addition, the recording will not be shared or sent through any internet or cloud-based system to prevent possible leaks. We understand that your privacy is important to you and we want you to be sure that what you do here today will not be watched by anyone that does not have the need to watch it.

There will be no negative consequences for stopping the interview, but it is very important for you to know that you have the power to stop the session if you feel it to be necessary.

Now, I ask a written permission from you to participate in the test that is recorded on audio and screen. Do you have some question at this point?

➔ *Hand the consent form*

(After signing the forms) Now, I will begin the interview. *(Start recording)*

- *Open the link of demo in a browser*
- *Briefly explain how to use the design. For example, how to use the mouse and click in the circles:*

The design contains responses of 50 people. The circles that you see are the categories of the question that people have answered in the survey. When you click in the circles, a rectangle appears and slowly splits. The number you are seeing in the rectangle indicate how many people among 50 have given what kind of responses.

- *Teach them how to use laptop and mouse*
- *First recommend them to watch the help video.*
- *Hand over the headphone.*
- *Make them watch the video. Take the headphone out.*
- *First tell them to ignore the text.*
- *Ask about each icons of the circles first. What they understand about icons. If not, make them understand.*
- *If participant gets confused:*
You can watch the help video over and over again if you would like to.

Now Let's begin.

Please click in gender icon/ circle.

- *How many men can you see?*
- *How many women can you see?*
- *How many other gender people can you see?*

Please click in Age icon/ circle

- *What do you understand from this graph?*
- *What did you not understand from this graph?*

If they do not understand, play the animation again by clicking different circle and clicking age circle again.

- How many people of age 0-14 years are there?
- How many total participants are there?

Please click the graph regarding Water

- Seeing this graph, how many people do you think have problem of Water facility?
- How many people do you think have enough Water facility?
- How many people do you think have partially enough Water facility?
- How many people do you think have no idea about water facility?

(Remind them about watching the help video, if they did not understand anything from the graph.)

Please click the graph regarding Food.

- How many do you think had full stomach or enough Food to eat?
- How many do you think had partially enough Food to eat??
- How many do you think had no enough Food to eat?
- How many people do not know about this?

Please open about education facility.

- From how many homes do all children go to school?
- From how many homes only some children go to school?
- From how many homes no children go to school?
- From how many homes, children are under 6?

Please open about electricity

- How many people enough electricity?
- How many people have partial electricity?
- How many people do not electricity?
- How many people do not know about this?

Please open about Health access

- How many people have good accessibility to Health facilities?
- How many people have partial accessibility to Health facilities?
- How many people do not have accessibility to Health facilities?
- How many people do not know about this?

Please open about Gender Equality

- How many people think that men and women are treated equally at work?
- How many people think that men and women are treated partially equal at work?
- How many people think that men and women are not treated equal at work?
- How many people do not know about this?

(You can also ask what the equality icons mean after this. It will be interesting to know do they still get the 4 icons. Also, at the end, Here ask the total number of workers who participated in the survey. It will be interesting to know do they remember the number of workers even after showing it several times)

How many do you think were the total number of workers who participated in the survey ()

Closing questions

- What do you think you did not understand in general?
- What do you think you did understand in general?
- What did you like about this design? Why?
- What did you not like about this design? Why?
- What do you think how can this be improved to make things understandable for you?
- Do you want some thoughts or comments you would like to say?
- Do you have anything to say?
- Do you still have any questions?

Thank you very much for taking your time. In the name of WorkAhead, I want to thank you for your commitment to this interview. Thank you.

(Stop Recording and attach the recordings in Google drive)